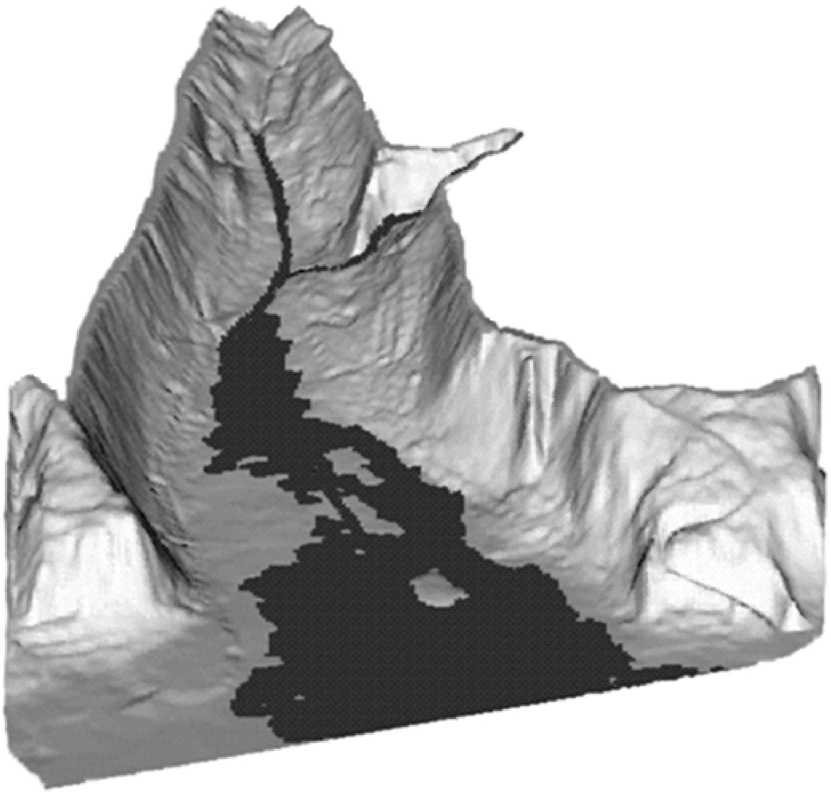
US Army Corps
of Engineers
Hydrologic Engineering Center

HEC-GeoRAS

An extension for support of HEC-RAS using ArcView



User's Manual

Version 3.1
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HEC-GeoRAS is an ArcView GIS extension specifically designed to process geospatial data for use with the Hydrologic Engineering Center River's Analysis System (HEC-RAS). The extension allows users with limited GIS experience to create an HEC-RAS import file containing geometric attribute data from an existing digital terrain model (DTM) and complementary data sets. Water surface profile results may also be processed to visualize inundation depths and boundaries.

HEC-GeoRAS is an ArcView GIS extension. ArcView GIS Version 3.2 and the 3D Analyst extension are required to use HEC-GeoRAS. Spatial Analyst is recommended.

*ArcView GIS is a general purpose geographic information system (GIS) software program developed and copyrighted by the Environmental Systems Research Institute, Inc., Redlands, CA.

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Table of Contents

Foreword

HEC-GeoRAS is an extension for use with ArcView GIS, a general purpose Geographic Information System software program developed and copyrighted by the Environmental Systems Research Institute, Inc., (ESRI) Redlands, California. HEC-GeoRAS is written in the Avenue programming language.

The HEC-GeoRAS extension was developed though a Cooperative Research and Development Agreement between the Hydrologic Engineering Center (HEC) and ESRI. HEC-GeoRAS Version 3.1 is the result of continued development by HEC of the AVRAS 2.2 extension, written by ESRI in cooperation with HEC.

Acknowledgements

Cameron T. Ackerman, Hydrology and Hydraulics Technology Division, HEC, was responsible for HEC-GeoRAS extension development and writing this user's manual. HEC-GeoRAS software development benefited from extensive input provided by Gary W. Brunner, HEC-RAS Team Leader, Hydrology and Hydraulics Technology Division, Mark Jensen, Hydrology and Hydraulics Technology Division, and Thomas A. Evans, Water Control Systems Division.

Initial software development for the HEC-GeoRAS extension was completed by Dean Djokic, ESRI, in cooperation with HEC. Dudley McFadden III, David Ford Consulting Engineers, assisted in the continued software development for Version 3.1.

Arlen D. Feldman was the Hydrology and Hydraulics Technology Division Chief and Darryl Davis was the Director during the development of HEC-GeoRAS.

The Hydrologic Engineering Center would like to acknowledge the Honolulu District and Sacramento District for providing the data sets used in the examples. **Note that the example figures in this manual are provided for illustrative purposes only and are not to be perceived as hydraulically accurate.**

CHAPTER 1

Introduction

HEC-GeoRAS is an ArcView GIS extension specifically designed to process geospatial data for use with the Hydrologic Engineering Center's River Analysis System (HEC-RAS). The extension allows users with limited GIS experience to create an HEC-RAS import file containing geometric attribute data from an existing digital terrain model (DTM) and complementary data sets. Results exported from HEC-RAS may also be processed.

The current version of HEC-GeoRAS creates an import file, referred to herein as the *RAS GIS Import File*, containing river, reach and station identifiers; cross-sectional cut lines; cross-sectional surface lines; cross-sectional bank stations; downstream reach lengths for the left overbank, main channel, and right overbank; and cross-sectional roughness coefficients. Additional geometric data defining levee alignments, ineffective flow areas, and storage areas may be written to the RAS GIS Import File. Hydraulic structure data are not written to the import file. Water surface profile data and velocity data exported from HEC-RAS may be processed into GIS data sets.

Chapter 1 discusses the intended use of HEC-GeoRAS and provides an overview of this manual.

Contents

- Intended Application of HEC-GeoRAS
- Overview of Requirements
- User's Manual Overview

Intended Application of HEC-GeoRAS

HEC-GeoRAS creates a file of geometric data for import into HEC-RAS. It also enables viewing of exported results from RAS. The import file is created from data extracted from data sets (ArcView shapefiles) and from a Digital Terrain Model (DTM). HEC-GeoRAS requires a DTM represented by a triangulated irregular network (TIN). The shapefiles and the DTM are referred to collectively as the *RAS Themes*. Geometric data is developed from calculating the intersection of the RAS Themes.

Prior to performing hydraulic computations in HEC-RAS, the geometric data must be imported and completed and flow data must be entered. Once the hydraulic computations are performed, exported water surface and velocity results from HEC-RAS may be imported back to the GIS using HEC-GeoRAS for spatial analysis. GIS data is transferred between HEC-RAS and ArcView using a specifically formatted GIS data exchange file.

Overview of Requirements

HEC-GeoRAS 3.1 is an ArcView GIS (Environmental Systems Research Institute, 1996) extension that provides the user with a set of procedures, tools, and utilities for the preparation of GIS data for import into RAS and generation of GIS data from RAS output. While the GeoRAS extension is designed for users with limited geographic information systems (GIS) experience, knowledge of ArcView GIS is advantageous. Users, however, must have experience modeling with HEC-RAS and have a thorough understanding of river hydraulics to properly create and interpret GIS data sets.

Hardware and Software Requirements

HEC-GeoRAS 3.1 is an extension for use with ArcView GIS 3.2, or higher, with the 3D Analyst 1.0 extension. While not required, the availability of the Spatial Analyst extension significantly speeds up post-processing. HEC-GeoRAS presently only runs on Windows 2000/NT/98/95.

The full functionality of HEC-GeoRAS 3.1 requires HEC-RAS 3.1. Older versions of HEC-RAS may be used, however, with limitations on importing roughness coefficients, ineffective flow data, levee data, and storage area data; exporting velocities; and filtering cross-section data points.

Data Requirements

HEC-GeoRAS requires a DTM in the form of a TIN. The DTM must be a continuous surface that includes the bottom of the river channel and the floodplain to be modeled. Because all cross-sectional data will be extracted from the DTM, only high-resolution DTMs should be considered for hydraulic modeling. Measurement units used are relative to those in the DTM. If the units of the DTM are not specified, they will not be written to the HEC-RAS import file.

User's Manual Overview

This manual provides detailed instruction for using the HEC-GeoRAS ArcView extension to develop geometric data for import into HEC-RAS and view results from HEC-RAS simulations. The manual is organized as follows:

Chapter 1-2 provides an introduction to HEC-GeoRAS, as well as instructions for installing the extension and getting started.

Chapter 3 provides a detailed overview of HEC-GeoRAS.

Chapter 4 describes HEC-RAS pre-processing requirements and detailed instruction for developing an HEC-RAS GIS Import File.

Chapter 5 describes HEC-RAS post-processing options and detailed instruction on developing a GIS data set from exported HEC-RAS results.

Chapter 6 provides an example application of HEC-GeoRAS for new users looking to learn basic functionality.

Chapter 7 provides an example application of HEC-GeoRAS for more experienced users seeking to learn the detailed extension functionality.

Appendix A contains a list of references.

Appendix B contains a sample import and export file.

CHAPTER 2

HEC-GeoRAS Installation

The installation procedure for the HEC-GeoRAS ArcView GIS extension is the same for Windows 2000/NT/98/95 operating systems.

This chapter discusses ArcView GIS requirements and instructions for installing the HEC-GeoRAS extension.

Contents

- Hardware and Software Requirements
- Installation
- Loading HEC-GeoRAS

Hardware and Software Requirements

HEC-GeoRAS 3.1 requires ArcView 3.2 GIS for Windows 95/98/NT/2000 and the 3D Analyst 1.0 extension. The availability of the Spatial Analyst 1.0 extension will speed-up the post-processing, but is not required. There are no additional requirements; however, you should identify the availability of disk space for creating GIS data sets.

Installation

The GeoRAS extension is installed and loaded as any other ArcView extension. To make the extension visible to ArcView, copy the file **hecgeoras.avx** to the ArcView extension subdirectory (AVHOME\ext32). The AVHOME directory is usually c:\esri\av_gis30.

Once the GeoRAS extension has been copied to the destination directory, it can be loaded from ArcView.

Loading HEC-GeoRAS

ArcView extensions are loaded through the File menu on the main ArcView window. Select the **File** ⇒ **Extensions** menu item. In the dialog that appears (see Figure 2-1), scroll down to the **HEC-GeoRAS** item and use the corresponding check box to turn it on. Press **OK** to close the dialog and load the HEC-GeoRAS extension.

The 3D Analyst extension automatically loads with the GeoRAS extension. If available, load the Spatial Analyst extension, as was done with the HEC-GeoRAS extension.

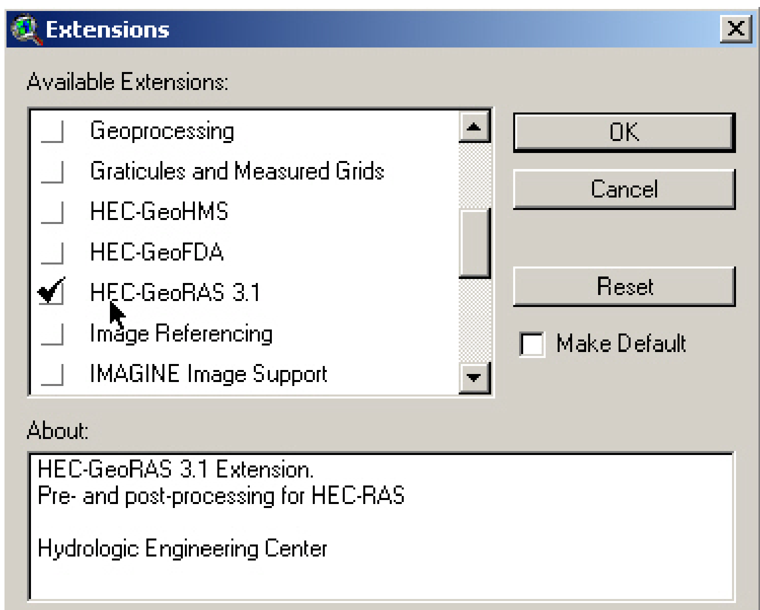


Figure 2-1. Load ArcView extensions dialog.

CHAPTER 3

Working with HEC-GeoRAS – An Overview

HEC-GeoRAS is a set of procedures, tools, and utilities for processing geospatial data in ArcView GIS using a graphical user interface (GUI). The interface allows the preparation of geometric data for import into HEC-RAS and processes simulation results exported from HEC-RAS.

To create the import file, the user must have an existing digital terrain model (DTM) of the river system in the ArcInfo TIN format. The user creates a series of line themes pertinent to developing geometric data for HEC-RAS. The themes created are the Stream Centerline, Flow Path Centerlines (*optional*), Main Channel Banks (*optional*), and Cross Section Cut Lines referred to, herein, as the *RAS Themes*.

Additional RAS Themes may be created/used to extract additional geometric data for import in HEC-RAS. These themes include Land Use, Levee Alignment, Ineffective Flow Areas, and Storage Areas.

Water surface profile data and velocity data exported from HEC-RAS simulations may be processed by HEC-GeoRAS for GIS analysis.

Chapter 3 provides an overview of the steps necessary to develop the RAS GIS Import File (for importing geometric data into HEC-RAS) and processing the RAS GIS Export File (results exported from HEC-RAS). It is also designed to familiarize the user with the ArcView environment. An overview diagram of the HEC-GeoRAS process is shown in Figure 3-1. Chapter 4 and Chapter 5 more completely discuss HEC-RAS data pre- and post-processing, respectively.

Contents

- Getting Started
- Developing the RAS GIS Import File
- Running RAS
- Processing the RAS GIS Export File

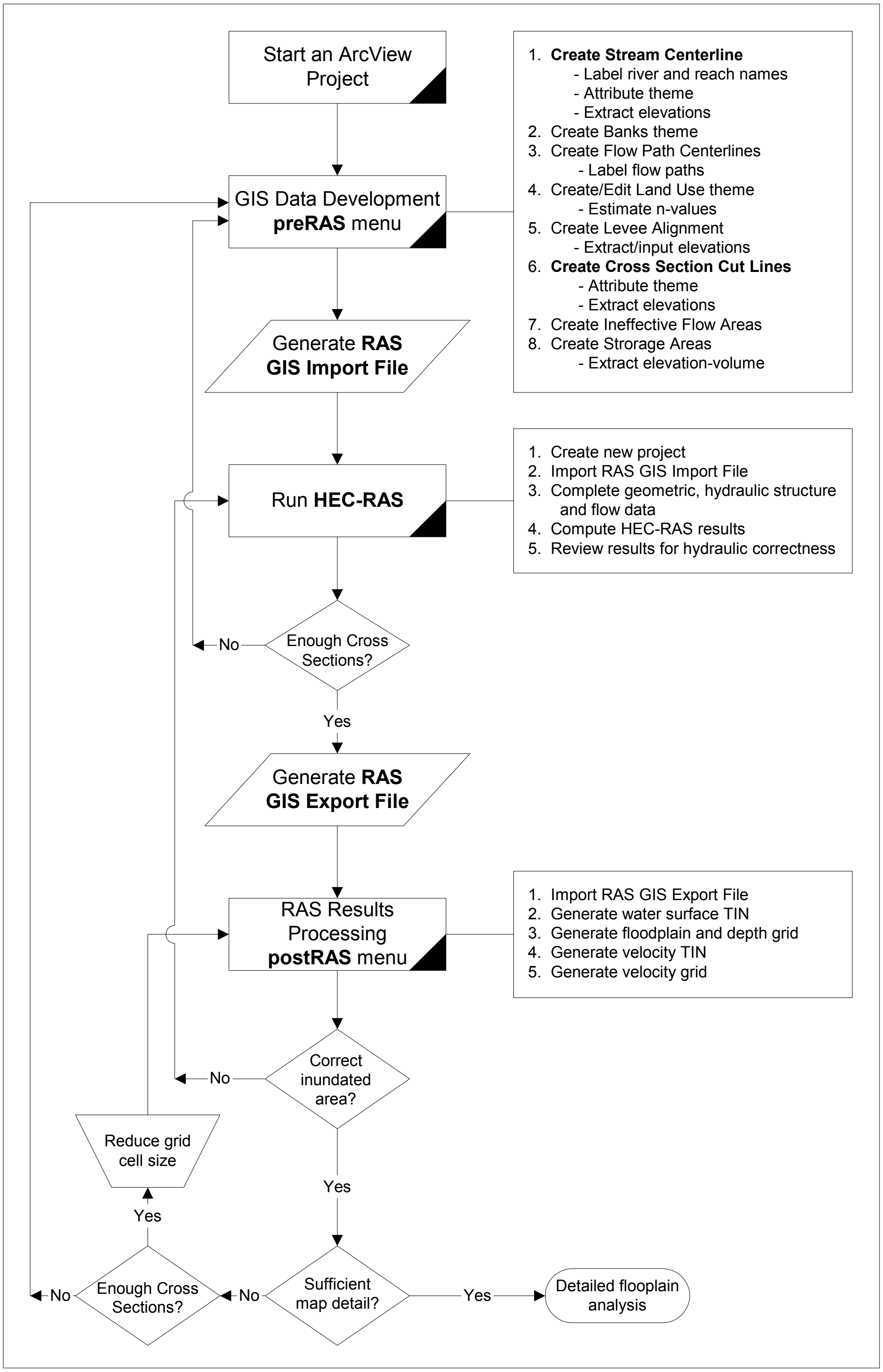


Figure 3-1. Process flow diagram for using HEC-GeoRAS.

Getting Started

Start ArcView GIS. Load the GeoRAS extension by selecting **File ⇒ Extensions...** on the main ArcView window and selecting **HEC-GeoRAS** from the extension choices. The 3D Analyst extension will automatically load. If available, load the Spatial Analyst extension to speed up post-processing.

When the GeoRAS extension loads, menus, buttons, and tools are added to the ArcView interface. These additions are intended to aid the user in stepping through the geometric data development process and post-processing of exported HEC-RAS simulation results. The GeoRAS extension menus, buttons, and tools are shown in Figure 3-2.

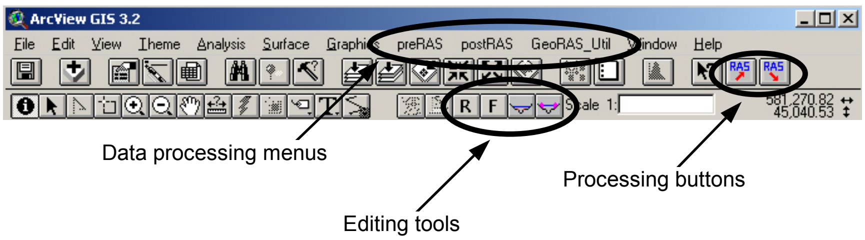


Figure 3-2. HEC-GeoRAS interface additions.

Menus

The HEC-GeoRAS preRAS, postRAS, and GeoRAS_Util menus displayed at the top of the ArcView interface are discussed below.

PreRAS

The preRAS menu option is used for pre-processing geometric data for import into HEC-RAS. Items in the preRAS dropdown menu are listed in the recommended (and sometimes required) order of completion. Items available from the preRAS menu items are shown in

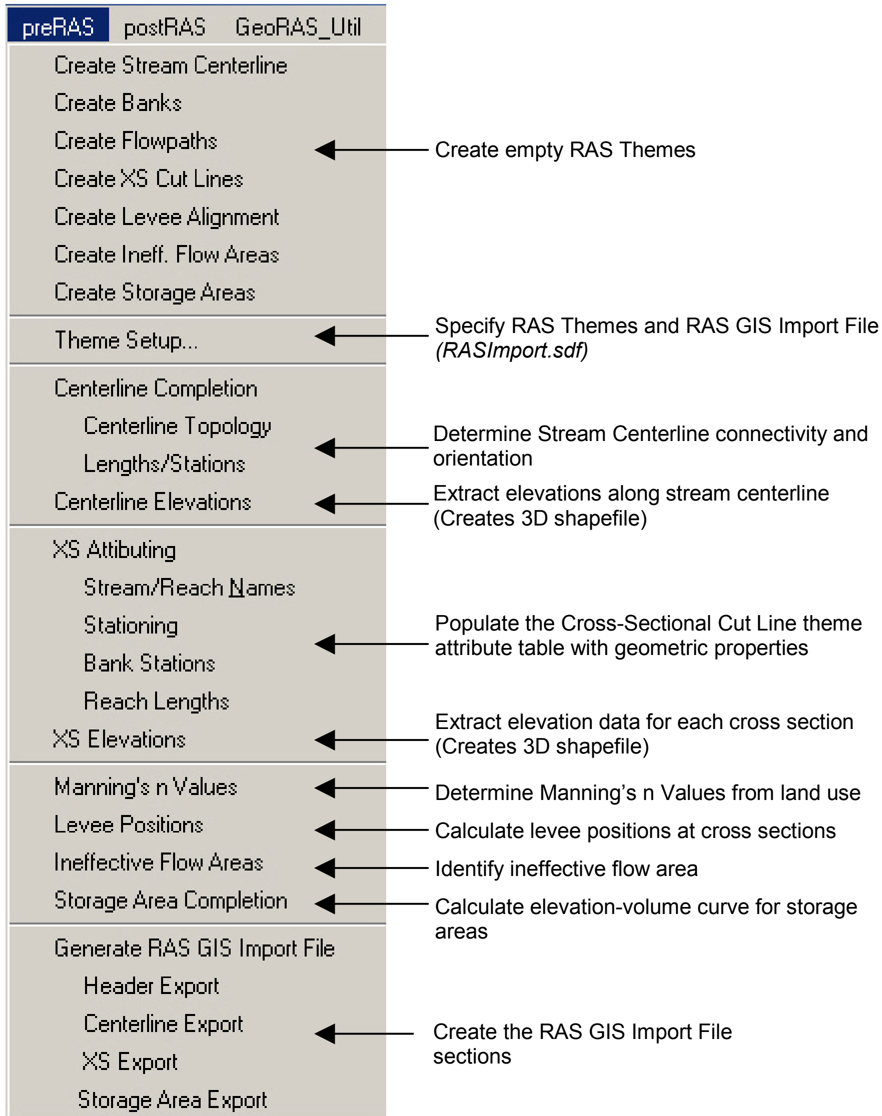


Figure 3-3. Pre-processing menu options.

PostRAS

The postRAS menu option is used for post-processing exported HEC-RAS results. Items available from the postRAS dropdown menu are listed in the order of completion. Items available from the postRAS menu are shown in Figure 3-4.

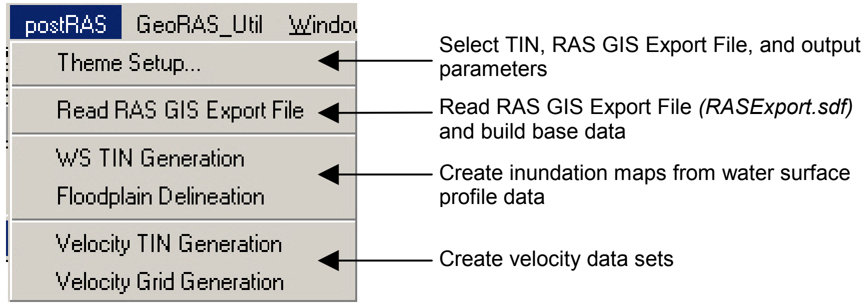


Figure 3-4. Post-processing menu options.

GeoRAS_Util

The GeoRAS_Util menu option provides utilities for editing themes and theme management. The procedures performed by these utilities are not required to develop geometric data sets, but are there to assist the user with various functions. GeoRAS_Util items are shown in Figure 3-5.

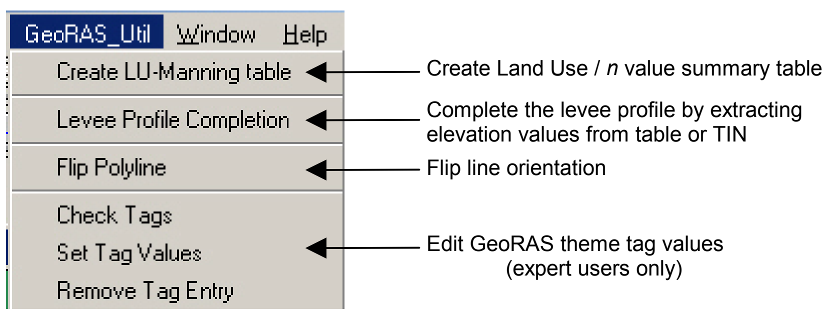
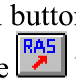


Figure 3-5. Utilities available when using HEC-GeoRAS.

Buttons

There are two buttons provided below the menu bar. A button initiates an action immediately after being pressed. The 

button generates the RAS GIS Import File, just as the Generate RAS Import File (summary of Header Export, Centerline Export, XS Export) item under the preRAS menu. The 

button imports the RAS GIS Export File by performing the Theme Setup and Read RAS Export File steps under the postRAS menu. These buttons should only be used after data sets have been verified and importing/exporting data have become repetitive tasks.

Tools

Tools, provided beneath the button bar on the ArcView interface, allow you to perform a specific action. A tool, when activated, turns a lighter color gray and looks as if it is depressed. The four tools added to the interface by GeoRAS are the (River ID); (Flowpath); (XS Plot); and (Levee) tools. The River ID and Flowpath tools allows you to provide a Stream ID and Reach ID for each reach in the Stream Centerline theme and to identify the left, middle, and right flow paths in the Flow Path Centerlines theme, respectively. The XS Plot tool allows you to preview the cross-sectional elevations and the Levee tool allows you to assign elevations to a levee alignment for interpolation.

Developing the RAS GIS Import File

The main steps in developing the RAS GIS Import File are as follow:

- Starting a New Project
- Creating RAS Themes
- Generating the RAS GIS Import File

Starting a New Project

You should save the ArcView project to the appropriate directory before creating any themes. This may require using the file browser to create and name a new directory. The directory to which the ArcView project is stored becomes the default directory when creating or adding new themes. It is the location where the RAS GIS Import File is written.

To save the project, select **File** ⇒ **Save Project** from the ArcView main interface, select the directory, input the project name, and press **OK**. ArcView projects are given the *.apr* file extension.

Once the project has been saved, start a new v*iew* by pressing the **New** button on the project window. The project window will be titled with the name of the current project. The *view* is composed of two parts: the *table of contents* and the *map display*. The *table of contents* lists the themes and the *map display* shows the features of the theme. **The HEC-GeoRAS extension is only visible on the ArcView interface if a *view* document is active.**

Next, load the DTM and any background themes for the river system to the new view. To load the Terrain TIN, press the (**Add Theme**) button or select the **View** ⇒ **Add Theme** menu item on the ArcView interface. This step invokes a browser. Select "*TIN Data Source*" from the *Data Source Type* pick list and browse to the location of the Terrain TIN. Select the TIN and press **OK**. The TIN is added to the current view.

You can load other themes using the same procedure by specifying the *Data Source Type* as a Feature, Image, Grid, or TIN.

Creating Contours

If the Terrain TIN is very detailed, it may not be appropriate to use for a background layer. (Extremely large TIN data sets take much longer to display to the screen than small TINs.) Line themes, such as contours, however, will normally display more quickly.

Make the TIN theme active in the view by selecting it from the table of contents with the mouse. This creates a box around the theme making it appear raised. Create a new theme of contour lines by selecting the **Surface** ⇒ **Create Contours** menu item. (The Surface menu was added to the ArcView interface when the 3D Analyst extension was loaded.) This invokes the dialog box shown in Figure 3-6. Next, enter the contouring parameters and press **OK**

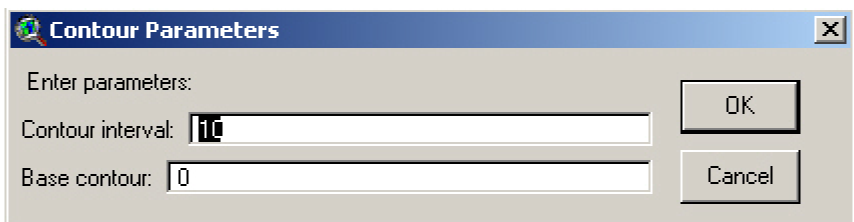


Figure 3-6. Dialog for entering contouring parameters.

ArcView will generate a theme of contours from the selected TIN with the default name of "Contours of *TINname*", where *TINname* is the name of the active TIN. If the contour interval specified is too fine in relation to the resolution of the TIN, ArcView may not properly process the data. If the interval specified is too large, the contour theme created will not provide an adequate visualization of the land surface.

To display the contour lines, click on the corresponding check box in the table of contents. If the contouring does not provide sufficient definition of the river network and main channel, create the contour theme again using a finer contour interval.

Creating RAS Themes

The next step is to create the RAS Themes that will be used for geometric data development and extraction. The line themes that need to be created are the Stream Centerline, the Main Channel Banks (*optional*), the Flow Path Centerlines (*optional*), and the Cross Section Cut Lines. Additional data sets you may wish to create include a polygon theme of land cover to estimate provide Manning's *n* values, a polyline theme of levee alignments, a polygon theme for representing ineffective flow areas, or a polygon theme to calculate floodplain storage areas. Existing shapefiles or ArcInfo coverages may be used for each RAS Theme; however, they will need to contain the attributes as specified in the following sections. If ArcInfo coverages are used, always convert them to a shapefile.

Feature themes are created using basic ArcView tools. The GeoRAS preRAS menu directs the user through the data development procedure. The following section provides an overview for creating the RAS Themes. Detailed descriptions on creating RAS Themes and theme structure are in Chapter 4.

Stream Centerline

The Stream Centerline theme should be created first. Select the **preRAS ⇒ Create Centerline Theme** menu item. The dialog shown in Figure 3-7 will appear. Enter the theme name and destination directory and press **OK**.

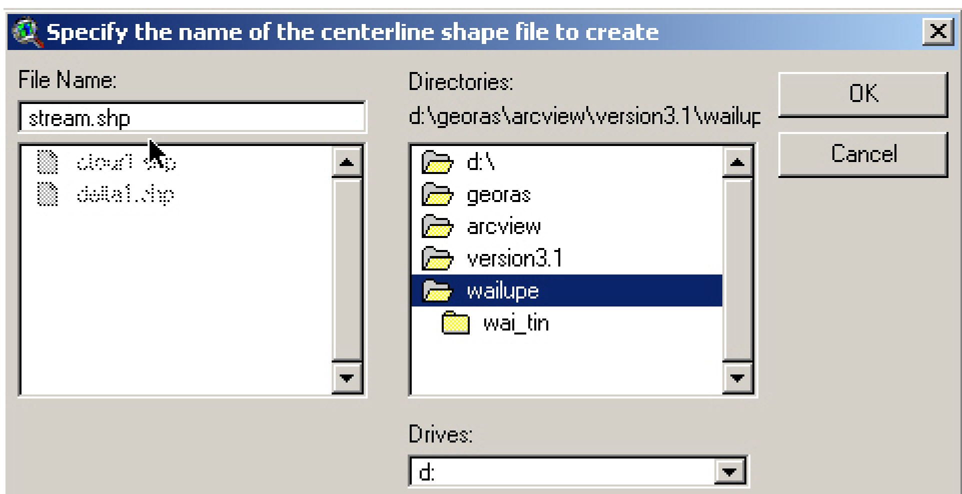


Figure 3-7. Standard file dialog window for specifying theme name.

The Stream Centerline theme is added to the current view; it is active and editable. To start adding features to the Stream Centerline theme, select the  (**Draw Line**) tool. Move the cursor over to the view's map display and cross hairs will appear. Draw river reaches one by one, from upstream to downstream using the mouse. Each reach is represented by one line having a series of vertices. To start a line use the mouse to left click, using left clicks to add vertices, and double-click to end a line. After creating the river network, select **View ⇒ Stop Editing**.

The Stream Centerline theme, however, is not complete until each River Reach has been assigned a name. Make sure the Stream

Centerline theme is still active and select the  (**River ID**) tool. Cross hairs will appear as the cursor is moved over the map display. Use the mouse to select a River Reach. The dialog shown in Figure 3-8 will be invoked to name the river and reach. Previously specified river names are available from a drop down list using the down arrow to the right of the river name field. Reach names for the same river must be unique. River and reach names may be up to 16 characters in length.

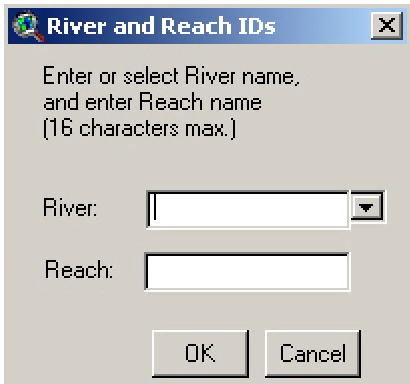


Figure 3-8. River and reach identification window.

Main Channel Banks

Select the **preRAS** ⇒ **Create Banks Theme** menu item. Enter the theme name and destination directory in the dialog that appears and press **OK**.

Use the **Draw Line** tool to draw the location of the channel banks. Separate lines should be used for the left and right bank of the river. Bank lines from tributary rivers may overlap the bank lines of the main stem. After defining each bank line, select **View** ⇒ **Stop Editing**. *Creating the Main Channel Banks theme is optional.*

Flow Path Centerlines

Select the **preRAS** ⇒ **Create Flowpath Theme** menu item. Enter the theme name and destination directory in the dialog that appears and press **OK**.

If the Stream Centerline theme exists, the centerline will be copied as the flow path for the main channel. Use the **Draw Line** tool to draw the hydraulic flow path (center of mass of flow) in the left and right overbank, in the upstream to downstream direction. When finished drawing and editing flow paths, select **View** ⇒ **Stop Editing**.

Each flow path must be labeled with an identifier of *Left*, *Middle*, *Right*, corresponding to the left overbank, main channel, or right overbank. One by one, use the  (**Flowpath**) tool to label each flow path. After activating the Flowpath tool, select each flow path with the cross-hairs cursor. This dialog shown in Figure 3-9 will appear allowing the user to select the correct flow path label from a list. *Creating the Flow Path Centerlines theme is optional.*

Figure 3-9. Label flow path window.

Cross-Sectional Cut Lines

Select the **preRAS** ⇒ **Create XS Cut Lines** menu item. Enter the theme name and destination directory in the dialog that appears and press **OK**.

Use the **Draw Line** tool to draw the locations where cross-sectional data should be extracted from the Terrain TIN. Each cross-sectional cut line should be drawn from the left overbank to the right overbank, when facing downstream. Cross-sectional cut lines are multi-segment lines that should be drawn perpendicular to the flow path lines. Cut lines must cross the main channel only once and no two cross sections may intersect.

Land Use

Land use data may be used to estimate Manning's *n* values for each cross section; however, *creating the land use theme and estimating n values is optional*. Load the Land Use polyline theme to the view using the **Add Theme** button. Make the theme active and select the **GeoRAS_Util** ⇒ **Create LU-Manning Table** menu item. The dialog shown in Figure 3-10 will be invoked, allowing you to select the land-use description field. Use the drop-down list to pick the field and press **OK**.

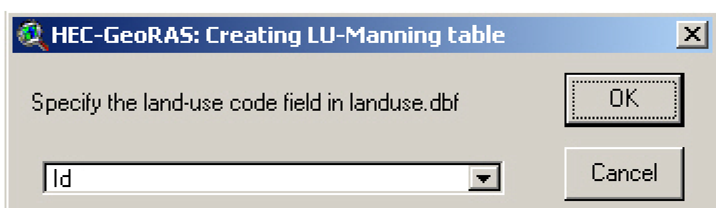


Figure 3-10. The user will need to specify which field to reference for the land use / Manning's n value relationship.

Another dialog will appear allowing you to specify a new table name and destination directory. Enter the table name ("lumanning.dbf" is default) and press **OK**.

The new table is a summary of all land-use descriptions and has a blank *N_value* field for Manning's *n* values. To edit the *N_value* field values the user will need to edit the new table.

From the *project* window, select the *tables* document. The name of the table ("lumanning.dbf") will appear as an available document. Double-click it to open it or select the table and press the **Open** button. The table will open with the field names across the top shown in italics with a gray background.

To edit the *N_value* field values, select **Table ⇒ Start Editing**. Note that the field names are no longer in italics, indicating that the table may be edited. Use the  (**Edit Cells**) tool to edit *n* values in the table. When finished entering *n* values, select **Table ⇒ Stop Editing**.

Select the view document used for creating the themes and the GeoRAS interface will appear.

Levee Alignment

Levee alignments may be specified in the geometric data. Select the **preRAS ⇒ Create Levee Alignment** menu item. Enter the theme name and destination directory in the dialog that appears and press **OK**.

Use the **Draw Line** tool to digitize the levee aligment(s). HEC-RAS currently allows only one levee per bank. Select the **GeoRAS_Util ⇒ Levee Profile Completion** to create a 3D shapefile from the levee alignment. If the levee alignments are for existing levees, GeoRAS will pick up elevations from the terrain TIN (assuming the levees are represented in the terrain). If, however, the alignments are proposed, you must specify the proposed levee elevations. Detailed instructions for editing levee elevations are given in Chapter 4. *Creating the Levee Alignment theme is optional*

Ineffective Flow Areas

Select the **preRAS ⇒ Create Ineff. Flow Areas** menu item. Enter the theme name and destination directory in the dialog that appears and press **OK**.

Use the  (**Draw Polygon**) tool to draw the location of the ineffective flow areas. Ineffective flow areas should intersect each cross section twice, indicating an "ineffective flow block". After defining each ineffective flow area, select **View ⇒ Stop Editing**. An ineffective flow "trigger" elevation may be specified by the user or based on the terrain data. Detailed instructions for editing ineffective flow area data are given in Chapter 4. *Creating the Ineffective Flow Areas theme is optional.*

Storage Areas

Storage areas may be used when modeling in unsteady flow. To create storage areas, select the **preRAS** ⇒ **Create Storage Areas** menu item. Enter the theme name and destination directory in the dialog that appears and press **OK**.

Use the  (**Draw Polygon**) tool to draw the location of the storage areas. In general, storage areas should not intersect cross sections as this would indicate an area simultaneously conveying water and storing water. After defining each storage area, select **View** ⇒ **Stop Editing**. Storage areas are used to compute elevation-volume relationships for floodplain storage. Detailed instructions for editing storage areas are given in Chapter 4. *Creating the Storage Areas theme is optional.*

Generating the RAS GIS Import File

After creating/editing each RAS Theme, select the **preRAS** ⇒ **Theme Setup** menu item. The pre-processing theme setup dialog shown in Figure 3-11 allows you to select the RAS Themes used for data development and extraction and to select the RAS GIS Export File name.

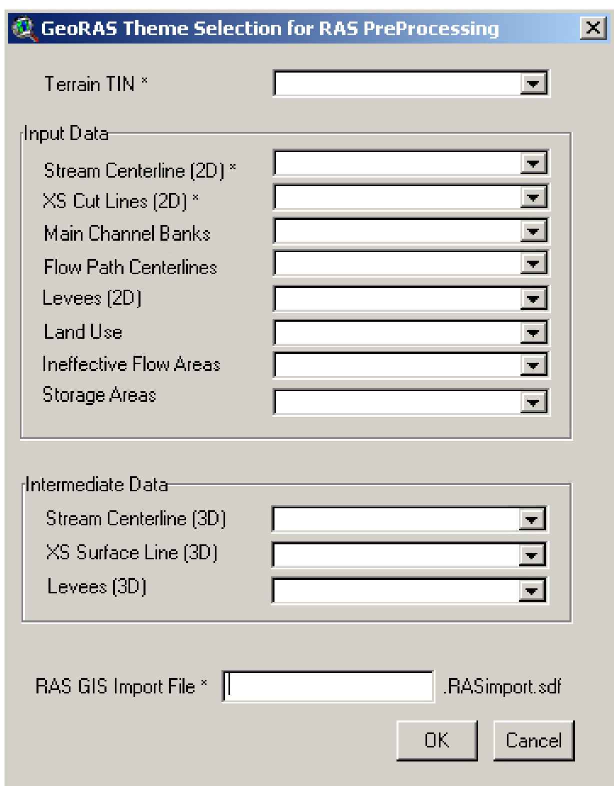


Figure 3-11. Pre-processing theme setup dialog.

Use the drop down lists to select the Terrain TIN and two-dimensional data inputs for processing. The three-dimensional data (intermediate data) will be derived along the way by GeoRAS. Also specify the RAS GIS Export File. *The file extension is ".RASimport.sdf"* and cannot be changed by the user . Press **OK** when finished.

Next, select the **preRAS ⇒ Centerline Completion** menu item. This process completes the centerline topology. Select **preRAS ⇒ Centerline Elevations** to create a new 3D shapefile. The user will be asked to name the shapefile ("stream3D.shp" is default) and select the destination directory.

The next step is to add the geometric attributes to the Cross Section Cut Line theme. Select the **preRAS ⇒ XS Attributing** menu item. Stream and reach, stationing, bank station, and downstream reach length information will be appended to each cross section cut line.

To complete the cross-sectional data, station-elevation data needs to be extracted from the Terrain Tin. Select the **preRAS ⇒ XS Elevations** menu item. This will create a cross-sectional surface line theme (a 3D shapefile, default name "xscutlines3D.shp") from the cross-sectional cut lines.

If you have a Land Use theme with estimated roughness coefficients, select the **preRAS ⇒ Manning's n Values** to determine the horizontal variation in Manning's *n* values along each cross section.

If you have a completed Levee Alignment (3D), select **preRAS ⇒ Levee Positions** to calculate the intersection of the levees at the cross sections.

If you have ineffective flow data, select the **preRAS ⇒ Ineffective Flow Areas** to calculate the location of ineffective flow areas at the cross sections.

If you have storage areas, select the **preRAS ⇒ Storage Areas** to calculate the elevation-volume relationship for each storage area of interest.

Lastly, select the **preRAS ⇒ Generate RAS GIS Import File** menu item. This step writes the header information, stream centerline information contained in the *Stream Centerline (3D)* theme, and cross-sectional information contained in the *XS Surface Lines (3D)* theme to the RAS GIS Import File in the HEC-RAS import file format. Manning's *n* values, levee alignment data, ineffective flow data, and storage data will be written, if available.

Running RAS

After importing the geometric data extracted from the GIS, completion of the hydraulic data will be necessary. Hydraulic data that is not imported includes contraction and expansion coefficients, hydraulic structure data such as bridges and culverts, and optional data such as levees and ineffective flow areas. Flow data and the associated boundary conditions need to be supplied, as well. For a more complete discussion on importing geometric data, refer to the HEC-RAS User's Manual, Chapter 13 (Hydrologic Engineering Center, 2002).

After running various simulations in HEC-RAS, export the results. For a more complete discussion on exporting GIS data, refer to the HEC-RAS User's Manual, Chapter 13 (Hydrologic Engineering Center, 2002).

Processing the RAS GIS Export File

The main steps in processing HEC-RAS results are:

- Reading the RAS GIS Export File
- Processing RAS Results Data

Reading the RAS GIS Export File

The first step for importing HEC-RAS results into the GIS is to select the RAS GIS Export File. Select the **postRAS ⇒ Theme Setup** menu item. The dialog shown in Figure 3-12 will appear to allow the user to select the RAS GIS Export File *(.RASExport.sdf)*. The dialog also allows the user to select the Terrain TIN used for floodplain delineation, identify the directory to write post-processing results to, and the cell rasterization size for grid calculations.

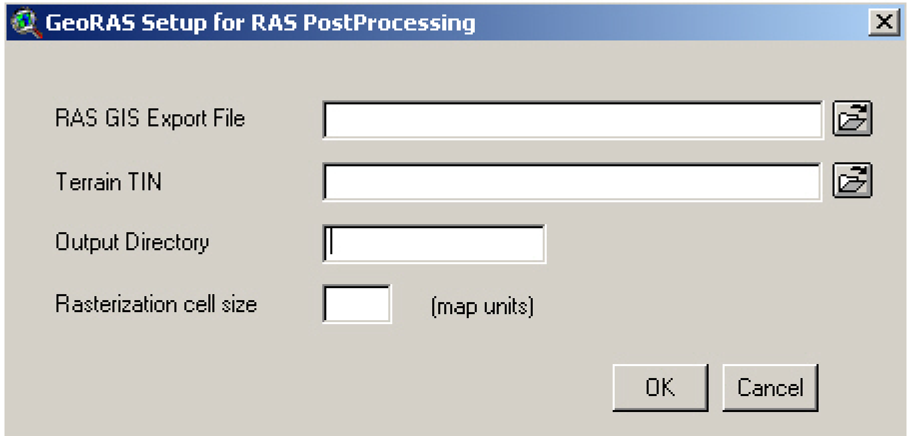


Figure 3-12. Post-processing theme setup dialog.

The output directory specified will be created one level down from where the GeoRAS project is stored. All post-processing results will be stored in the Output Directory. The Output Directory is the directory name only (NOT the entire pathname).

Select the **postRAS ⇒ Read RAS GIS Export File** menu item. HEC-GeoRAS will read the export file and begin creating preliminary data sets. Preliminary shapefiles created include the following:

- Stream network shapefile
- Cross section cut lines shapefile
- Bounding polygon shapefiles for each water surface profile
- Main channel banks shapefile (optional)
- Velocity point shapefile for each water surface profile (optional)
- Storage areas polygon shapefile (optional)

These data sets are created without user input and will be used later for building inundation and velocity data sets.

Processing RAS Results Data

Post-processing of RAS results creates GIS themes for inundation and velocity analysis. All GIS themes developed during RAS post-processing are based on the content of the RAS GIS Export File and the Terrain TIN. For data consistency, the same Terrain TIN used for generation of the RAS GIS Import File should be used for post-processing. A **maximum of 10 water surface profiles** can be processed for a given GeoRAS project (due to ArcView limitations).

Inundation Results

Once the RAS GIS Export File has been read, the user can begin creating inundation data sets. The first step is to create water surface TINs for each water surface profile. Select the **postRAS ⇒ WS TIN Generation** menu item. This will invoke a dialog with a pick list of water surface profile names. Multiple water surface profiles may be selected by holding down the SHIFT key during selection. Press **OK** to build the water surface TINs.

One water surface TIN will be created for each selected water surface profile. The TIN is created based on the water surface elevation at each cross section and the bounding polygon data specified in the RAS GIS Export File. The water surface TIN is generated without considering the Terrain TIN.

The floodplain may then be delineated for each water surface profile for which a water surface TIN exists. Select the **postRAS ⇒ Floodplain Delineation** menu item.

A floodplain polygon will be created for each water surface profile TIN that was created previously. Each floodplain polygon results from intersecting the water surface and terrain surface. The floodplain delineation procedure converts the water surface TIN and Terrain TIN to lattices (grids) with the same cell size and origin. A depth grid is then created wherever the water surface grid is higher than the terrain grid. The depth grid is converted to the floodplain polygon.

If the Spatial Analyst extension is available, the water depth grid computations will be optimized. If the Spatial Analyst is not present, a point theme will also be generated, with the depth of the water at each point as an attribute.

Velocity Results

Velocity data sets may be generated after performing the floodplain delineation. Select the **postRAS ⇒ Velocity TIN Generation** menu item. A dialog will appear allowing the user to select water surface profiles. The pick list will only contain the names for which the floodplain has been delineated. Velocity TINs will then be created with bounds and identified by the associated floodplain polygon.

After creating a velocity TIN, a velocity grid may be computed using the **postRAS ⇒ Velocity Grid Generation** menu item. Velocity results must be interpreted carefully. Velocity data exported from HEC-RAS are accurate estimates at each cross section; however, interpolation results away from cross sections may be poor.

CHAPTER 4

Developing the RAS GIS Import File

The RAS GIS Import File consists of geometric attribute data necessary to perform hydraulic computations in HEC-RAS. The cross-sectional geometric data is developed from an existing Digital Terrain Model (DTM) of the channel and surrounding land surface, while the cross-sectional attributes are derived from points of intersection of RAS Themes. The DTM must be in the form a triangulated irregular network (TIN).

RAS Themes created include the Stream Centerline, Main Channel Banks (*optional*), Flow Path Centerlines (*optional*), and Cross-Sectional Cut Lines, Land Use (*optional*), Levee Alignment (*optional*), Ineffective Flow Areas (*optional*), and Storage Areas (*optional*). Geometric data and cross-sectional attributes are extracted from the DTM and RAS Themes to generate a file that contains: river, reach, and station identifiers; cross-sectional cut lines; cross-sectional surface lines; cross-sectional bank stations; and downstream reach lengths for the left overbank, main channel; and right overbank. Optionally, a land use polygon theme may be specified to extract roughness coefficients; levee alignments may be used to specify flow impediments; ineffective flow areas may be used to identify non-conveying flow areas; and storage areas may be used to develop elevation-volume relationships for unsteady-flow modeling.

Expansion/contraction coefficients and hydraulic structure data such as bridges and culverts are not written to the RAS GIS Import File.

Chapter 4 discusses the steps in developing the RAS GIS Import File.

Contents

- Flow Path Centerlines Theme
- Cross-Sectional Cut Lines Theme
- Land Use Theme
- Levee Alignment Theme
- Ineffective Flow Areas Theme
- Storage Areas Theme
- Generating the RAS GIS Import File

Digital Terrain Model

HEC-GeoRAS requires an existing DTM in the form of a TIN. The TIN must be representative of both the land surface of the channel bottom and adjacent floodplain areas. The TIN should be constructed to depict the floodplain interest from elevation point data and breaklines identifying linear features of the landscape. Elevation data for each cross section is extracted from the DTM. The DTM will also be used for determining floodplain boundaries and calculating inundation depths.

Developing a hydraulic model begins with an accurate geometric description of the surrounding landform, especially the channel geometry. Channel geometry typically dictates flow in river systems; therefore, only DTMs describing channel geometry with high accuracy and resolution should be considered for the basis of performing hydraulic analysis. Further, **RAS Themes should be created with thoughtful evaluation of the river hydraulics as governed by the terrain.**

Contours

Creating a theme of contours from a TIN theme is not required to use GeoRAS. However, it is often a logical first step that helps the user visualize the study area. Displaying the Terrain TIN provides detailed information on the river network and floodplain, but the display may prove too time-consuming to refresh during digitizing, panning, and zooming. The contour line theme, however, will refresh quickly and provide a good visual for delineating the river network and locating cross sections.

To create contours from a TIN, make the Terrain TIN theme active and select the **Surface** ⇒ **Create Contours** menu item. Enter the contour interval in the dialog that appears (see Figure 4-1) and press **OK**. The contour interval should be based on the definition of the Terrain TIN. "Contour interval" units will be based on the Terrain TIN, while the "Base contour" will be the elevation assigned to the first contour.

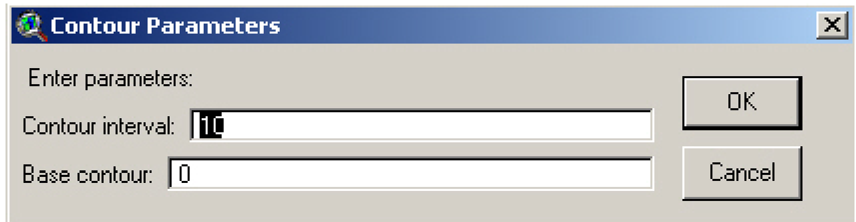


Figure 4-1. Contour parameters dialog.

It should take only a minute or so to create the contours, depending on the contour interval specified and the number of points in the Terrain TIN. The status bar at the bottom of the ArcView interface will inform you of the contouring process. When completed, the contour line theme will be added to the current view's table of contents. **The contour theme is intended for visualization only, and is not used during the data extraction process**.

Stream Centerline Theme

The river and reach network is represented by the Stream Centerline theme. The network is created on a reach by reach basis, starting from the upstream end and working downstream following the channel thalweg. Each reach is comprised of a River Name and a Reach Name.

The Stream Centerline is used for assigning river stationing to cross sections and to display as a schematic in the HEC-RAS Geometric editor. It may also be used to define the main channel flow path.

Rules!

- All river reaches must be connected at junctions. Junctions are formed when the downstream endpoint (TO node) of a reach coincides with the upstream endpoint (FROM node) of another reach.

- The Stream Centerline arcs must point downstream: the line must start at the upstream end and finish at the downstream end (the FROM node of the arc upstream of the TO node).

- Each river reach must have a unique combination of its River Name (Stream ID) and Reach Name (Reach ID).

- Stream Centerlines should not intersect, except at junctions where endpoints are coincident.

- Junctions are formed from the intersection of two (or more) rivers, each having a different River Name (Stream ID).

Creating the River Network

Select the **preRAS ⇒ Create Stream Centerline** menu item. This will create a new shapefile (default name of "Stream.shp*")* with *Stream_ID* and *Reach_ID* fields in the associated table.   The Stream Centerline theme will be added to the current view and will be active and editable. Create the stream network by digitizing and connecting reaches in the downstream direction.

To create a river reach, select the **Draw Line** tool. Use the left mouse button to begin a reach. Create the reach downstream using the left mouse button to add vertices along the way. When finished creating a reach, double-click the left mouse button.

Interactive pan and zoom options are available when editing a theme. Use a right click, when digitizing on screen, to invoke the popup menu. When the pan option is selected, for instance, the window will pan to make the current cursor location the center of the screen.

After creating the river network, select **Theme ⇒ Stop Editing**. Complete the Stream Centerline theme by adding river and reach identifiers using the 
 (**River ID**) tool. After activating the River ID tool, select a reach with the cross-hairs cursor. Enter the River Name and Reach Name in the dialog shown in Figure 4-2.

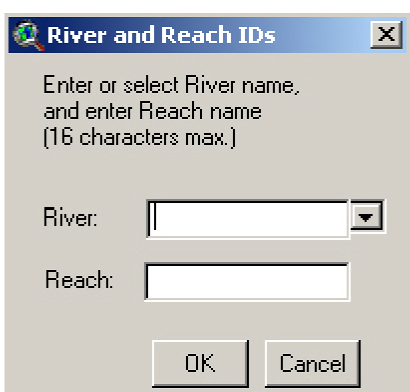


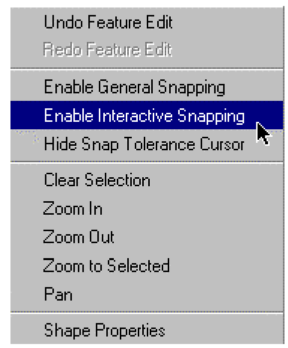
Figure 4-2. River and Reach Name dialog.

Junctions

Junctions are formed at the confluence of three or more reaches. Note that in HEC-RAS, you may only have a new reach (junction) at a flow change location. In order for a junction to be formed, reach endpoints must be coincident. Two ways for insuring junctions are formed at endpoints is discussed below.

Interactive snapping

Interactive snapping is used while creating a line and is the preferred method for snapping endpoints. Before creating a line using the **Draw Line** tool, right click in the display window. From the popup window (contents may vary depending on what mode the user is in) select **Enable Interactive Snapping** using the left mouse button.

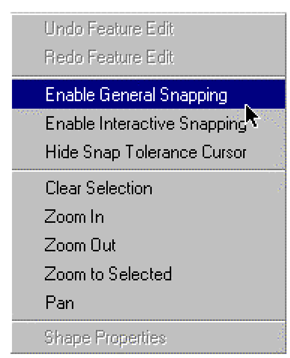


Next activate the  (**Snap**) tool that appears on the tool bar. This allows the user to select the interactive snapping tolerance visually. Use the cursor in the display window to draw the snapping distance (press and hold the left mouse button, release when desired).

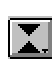
Once the interactive snapping is on, and the tolerance has been set, the user can snap endpoints on the fly. To snap the endpoint of one reach at a junction, right click on the display screen just before placing the downstream endpoint. Select **Snap to Endpoint** from the popup window. To end the line, double-click within the snap tolerance of the other endpoint - it will snap to the other endpoint forming a junction.

General snapping

General snapping can be used to form a junction after river reaches have already been created. This method is not recommended (although often necessary) because vertices may be snapped to the wrong location.



From the popup window (contents may vary depending on the mode) select **Enable General Snapping** using the left mouse button.

Next activate the  (**Snap**) tool that appears on the tool bar. This allows you to select the interactive snapping tolerance visually. Use the cursor in the display window to draw the snapping distance (choose a small snapping distance, it helps if you are zoomed in).

Once the general snapping has been set the user can adjust vertices of previously created lines. Vertices of new lines will also snap to vertices within the snap tolerance, so be wary. To snap the endpoint of an existing line, select the  (**Vertex Edit**) tool (a line theme must be active and editable). Select the endpoint to move by clicking once at the endpoint. Move the endpoint near the junction by pressing down on the left mouse button and dragging the endpoint. At the junction release the mouse button. Do not drag the endpoint all the way to the junction, but near the junction (just within the snap tolerance). The user will see the endpoint snap to the other endpoint (vertex) if the move was close enough. Make sure the endpoint snaps to the correct vertex!

Uniqueness

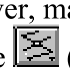
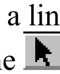
The stream network must have unique reach names for each river. Use the **River ID** tool to check that each reach on a river has a unique name or open the Stream Centerline attribute table.

Directionality

The Stream Centerline theme must be created in the downstream direction. To check the orientation of the river network, change the line symbol to a line symbol with arrows.

Adding Tributaries to a Network

Tributaries are added to an existing river network at a junction. If the junction already exists, simply add the new river reach using the interactive snapping method described earlier at the endpoint.

To add a tributary to the middle of a river reach, the reach must first be split. To split a river, make the Stream Centerline active and editable and select the  (**Split**) tool from the tool bar. This tool allows the user to draw a line across the existing river reach. After the reach is split, use the  (**Select Features)** tool to select and delete the extraneous two lines. Second, use the **River ID** tool to edit the reach names so that they are unique. Last, add the tributary using the interactive snapping method, described earlier, to snap the endpoint at the junction.

A simpler step might be to just create the new tributary using the **Split** tool. Digitize the tributary down to the main reach and then simply cross the reach where the junction should be. This will automatically split the existing river reach and form a junction. Next, delete the extraneous line (the overlapping end of the new tributary) and use the **River ID** tool to edit the River and Reach names.

Adding Reaches to a Network

The Stream Centerline theme must be active and editable. To add a reach to an existing river network, split the reach at the desired location using the **Split** tool. Use the **River ID** tool to edit the two reach names.

Merging Reaches in a Network

The Stream Centerline theme must be active and editable. Use the **Select Features** tool to select the two river reaches. (The reaches must share common endpoints.) Select the **Edit ⇒ Union Features** menu item. Use the **River ID** tool to check the reach name of the new reach. Make sure the two reaches share an endpoint when performing this task!

Main Channel Banks Theme

The Main Channel Banks theme defines the main channel flow from flow in the overbanks.

Cross-sectional bank stations will be assigned based on the intersection of Main Channel Banks theme and the cross-sectional cut lines.

Rules!

- Exactly two bank lines may cross each cross-sectional cut line.
- Bank lines may be broken.
- Orientation of bank lines is not important.
- Creating this theme is optional.

Creating the Bank Station Lines

Select the **preRAS ⇒ Create Banks** menu item. This will create a new shapefile (default name of "Banks.shp") and add it to the current view. The theme will be active and editable.

Bank station lines should be created on either side of the channel to differentiate the main conveyance channel from the overbank areas.

To add bank station lines, select the **Draw Line** tool. Use the left mouse button to start the line and to place vertices. Double-click the left mouse button when finished with the line.

Create bank lines for each side of the channel for each river. Bank station lines of tributaries may overlap those of the main channel. Cross-sectional cut lines may only intersect two bank station lines.

When finished editing the **Banks** theme, select **Theme ⇒ Stop Editing**.

Flow Path Centerlines Theme

The Flow Path Centerlines theme is used to identify the hydraulic flow path in the left overbank, main channel, and right overbank by identifying the center of mass of flow. If the Stream Centerline theme already exists you have the option to copy the stream centerline for the flow path in the main channel. Flow paths must be created in the direction of flow (upstream to downstream).

Downstream reach lengths are calculated between cross-sectional cut lines along the flow path centerlines for the left overbank, main channel, and right overbank.

Rules!

- Flow path lines must point downstream - in the direction of flow - (the FROM node upstream of the TO node).
- Each flow path must cross each cross-sectional cut line exactly once.
- Flow path lines should not intersect.
- Creating this theme is optional.

Creating the Flow Path Centerlines

Select the **preRAS ⇒ Create Flowpaths** menu item. This will create a new shapefile (default name of "Flowpath.shp") with the *LineType* field and add it to the view. The *LineType* field is used to identify the flow path in the **left** overbank, main **channel**, or **right** overbank. The flow path theme will be active and editable.

If the Stream Centerline theme was created previously using the Create Stream Centerline item on the preRAS menu, the dialog shown in Figure 4-3 will be invoked allowing the user to copy the stream centerline shape to the flow path theme.

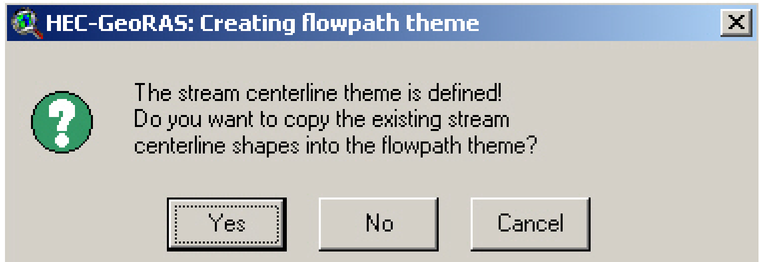


Figure 4-3. Copy the stream centerline to the Flow Path Centerline theme.

Complete the Flow Path Centerlines theme by drawing (digitizing) in the flow paths in the overbank areas. Begin by selecting the **Draw Line** tool. Draw the flow path lines in the direction of flow (upstream to downstream) using the left mouse button to start the line (left-click), add vertices (left-click), and end the line (double-left-click).

Be sure the flow path lines are drawn in the downstream direction. To check, change the line symbol to a line symbol with arrows. Each flow path line must cross a cross-sectional cut line exactly once and should not cross each other.

When finished creating the Flow Path theme, select **Theme** ⇒ **Stop Editing**.

Cross-Sectional Cut Lines Theme

The location, position, and extent of cross sections are represented by the Cross-Sectional Cut Lines theme. Cut lines should be perpendicular to the direction of flow and at times it may be necessary to dog-leg the cross-sectional cut line to conform to this requirement.

While the cut lines represent the planar location of the cross sections, the station elevation-data is extracted along the cut line from the DTM.

Rules!

- Cross-sectional cut lines must be pointed from the left overbank to right overbank, when looking downstream.
- Cut lines should be perpendicular to the direction of flow (considering the range of flow events).
- Cross-sectional cut lines should not intersect.

- Cross-sectional cut lines must cross each of the three flow path lines and two bank station lines exactly once.
- Cut lines must not extend beyond the extent of the Terrain TIN!

Creating Cross-Sectional Cut Lines

Select the **preRAS ⇒ Create XS Cut Lines** menu item. This will create a new shapefile (default name of "Xscutlines.shp"), add it to the view, and make it active and editable.

Add the location of each cross section using the **Draw Line** tool. Begin on the left overbank area (when facing downstream) and click the left mouse button to begin the cut line. Use the left mouse button to place vertices and left double-click when finished with the cut line. The cut lines should be drawn perpendicular to the direction of flow, cross a reach line exactly once, and should not cross another cut line. Be sure that the cut line covers the entire extent of the floodplain and does not extend beyond the extent of the Terrain TIN.

Check the cross section by changing the line symbol to a line symbol with arrows, on the symbol palette. If the cut line was constructed in the incorrect direction, it can be flipped using the **Flip Polyline** item available under the utility menu. To flip the cut line, select the line using the **Select Feature** tool. Next, select the **GeoRAS_Util ⇒ Flip Polyline** menu item.

When finished editing the Cross-Sectional Cut Line theme, select **Theme ⇒ Stop Editing**.

Previewing Cross Sections

Cross section profiles can be previewed using the  (**XS Plot**) tool. To preview a cross section, select the **XS Plot** tool. GeoRAS will extract the elevation data for each cross section and write it to a scratch file ("xsplot.dbf") located in the GeoRAS project file directory. If the file already exists, a dialog will be invoked asking the user to overwrite the data. Only overwrite the data if the placement of the cross sections has changed or you have added cut lines since the last time using the XS Plot tool.

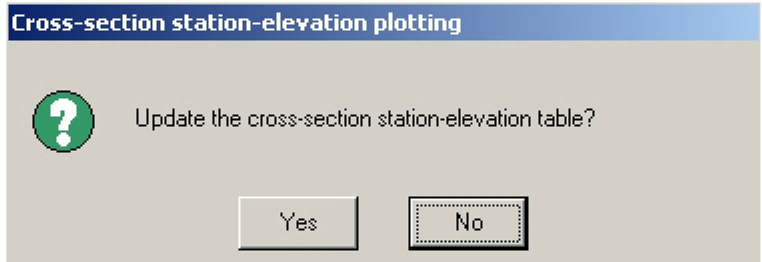


Figure 4-4. Overwriting cross-sectional data is only required if cut lines have been modified since last using the XS Plot tool.

Once the cross-section station-elevation data has been extracted to the scratch file, a cursor ( ) will appear allowing the user to select a cross section to preview. Use the cursor to select a cross-sectional cut line. When selected, the cut line will be highlighted and the cross section will be plotted in a charting window titled "XS Plot" with labeled axis.

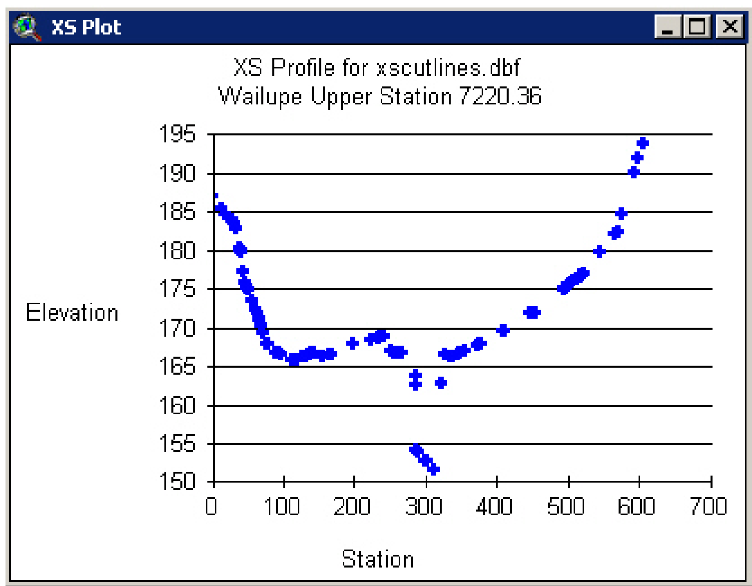


Figure 4-5. XS Plot

The chart will be titled using the Stream ID and Reach ID and Station. If this information has not been identified, a cross section ID will be applied. The x-axis is labeled "Station" and the y-axis is labeled "Elevation". The units used for display will be the default units for the underlying Terrain TIN.

When the XS Plot window is active, the (**Point Identify**) tool will be available. The Point Identify tool allows the user to identify a point in the cross section in plan view. To identify a point, select the Point Identify tool then click on a point in the cross section plotted. A red graphic dot will be drawn in the view document along the cross section at the selected point. The view will be centered to the point (to insure it is visible). Additional points may be added using the Point Identify tool for the same or different cross sections.

To remove graphic dots from the screen, use the  (**Pointer**) Tool to select the graphic dot and press the DELETE key. Alternatively, all graphics can be deleted by selecting **Edit** ⇒ **Select All Graphics** and pressing the DELETE key.

Land Use Theme

A polygon theme may be used to estimate Manning's *n* values along each cut line. If the polygon theme used is a land use theme, an additional field titled *N_value* will need to be added.

GeoRAS provides functionality to create a summary table of land uses and user specified *n* values. The table of *n* values is then joined to the land use data tables. Alternatively, a field titled *N_value* may be added to the land use table using standard ArcView functionality. Extracting *n* values at cross sections is an optional process.

Rules!

- Land use theme must be a polygon data set that encompasses the entire expanse of each cross section.
- The land use theme must have a field titled *N_value*.

Creating the Land Use Table

The Land Use polygon theme must have a *N_value* field. To add the field to the land use shapefile, activate the land use theme and select the **GeoRAS** ⇒ **Create LU-Manning Table** menu item. This will invoke a dialog (see Figure 4-6) to allow the user specify which field will be referenced for the land use attributes. Select the field name and press **OK**.

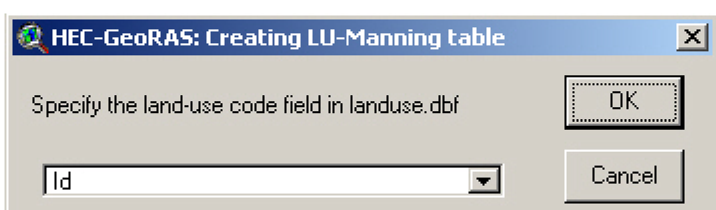


Figure 4-6. Land use field selection dialog.

The attributes of the selected field will be summarized and written to a new table. The default name for the table will be "lumanning.dbf" and will be stored in the project directory. The dialog browser shown in Figure 4-7 will appear and allow you to change the file name and location.

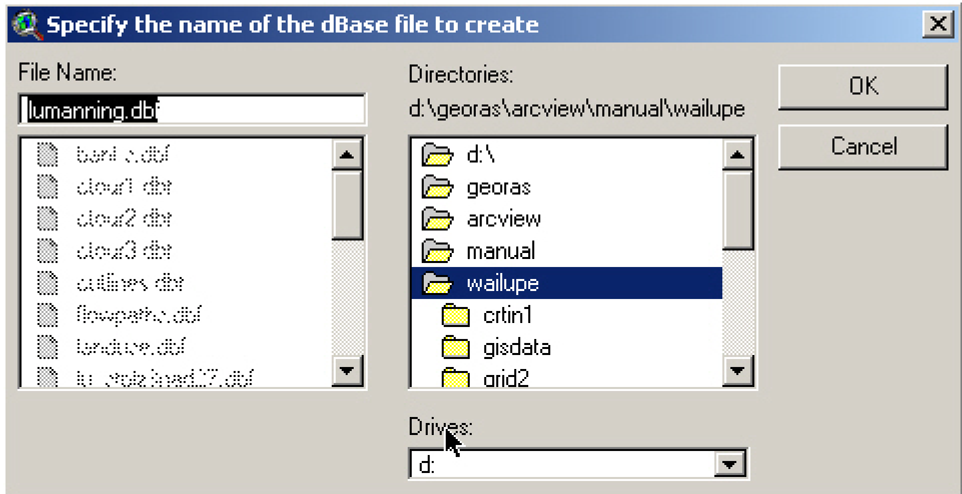


Figure 4-7. Summary n value table naming dialog.

The "lumanning" table created will have the land use field and an *N_value* field. To edit the n-value field, select the **Tables** document from the project window. The new table ("lumanning.dbf") will be listed. Select the table and press the **Open** button. Note that the field headings are in *italics, indicating that the table is not editable.*

Make the table editable by selecting **Table** ⇒ **Start Editing**. (The field headings will be in normal text.) Use the  (**Edit**) tool to enter *n* values corresponding to land use. After entering each *n* value be sure to hit the ENTER key or click in a new cell to record the value (especially on the last entry). When finished entering values, select **Table** ⇒ **Stop Editing**.

Note that the "lumanning.dbf" table is joined to the land use data set. Therefore, the land use shapefile and lumanning database file need to be kept together (referenced in the ArcView project). Each time the ArcView project (*.apr*) is opened, the tables will be joined using the ArcView **Join** function. To keep user defined *n* values with the land use data, create a new shapefile with the attached *n*-value data. Make the land use theme active. Make sure that all records are unselected and select the **Theme** ⇒ **Convert to Shapefile** menu item.

Levee Alignment Theme

The Levee Alignment theme is used to delineate linear features that obstruct the lateral flow of water in the floodplain. This theme is intended to be used on leveed systems, but should also be used to indicate high roads or ridges that connect multiple cross sections.

Note that HEC-RAS Version 3.1 only supports one levee per overbank per cross section – one levee in the left overbank, one levee in the right overbank.

The levee alignment tools are intended to work with both "existing" and "proposed" levees. "Existing" levees means levees that are reflected in the Terrain TIN, while "proposed" levees indicate the levee profile data is not represented in the Terrain TIN.

Rules!

- Levee lines may intersect each cross section only once.
- One levee per bank (HEC-RAS 3.1 limitation).
- Levee alignment table must have the field titled *Levee_ID*.

Creating Levee Alignments

Select the **preRAS** ⇒ **Create Levee Alignment** menu item. This will create a new shapefile (default name of "levees.shp"), add it to the view, and make it active and editable.

Add the location of each levee using the **Draw Line** tool. Left-click to start a line and add vertices and double-click to end the levee line. After creating each levee line, open the Levee Alignment table. The table contains the field *Levee_ID*. This is a required field.

Make the table editable by selecting **Table** ⇒ **Start Editing**. Use the (**Edit**) tool to enter an identifier for each levee alignment in the *Levee_ID* field. The identifier may be a character string up to 16 characters long and must not have spaces in the name. After entering each identifier be sure to hit the ENTER key or click in a new cell to record the value (especially on the last entry). When finished entering values, select **Table** ⇒ **Stop Editing**.

Entering Levee Profile Data

Levee profile data may be entered using the (**Levee Elevations**) tool. This option is necessary to create a levee that is not represented in the terrain TIN. To enter elevations along a levee, select the **Levee Elevation** tool. Using the (Bullseye **Pointer**), click on a specific point along a levee. The levee will become selected and a screen allowing the user to specify an elevation will appear, as shown in Figure 4-8.

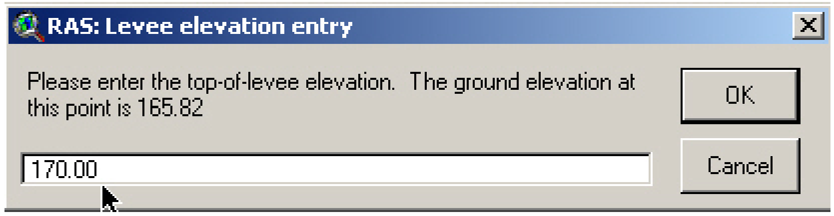
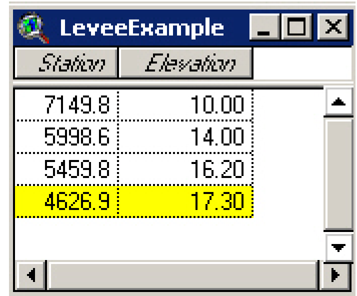


Figure 4-8. User-specified levee profile data dialog.

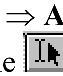
The elevation point entered will be saved in a levee-specific table automatically generated. The table will be labeled using a concatenation of "Levee" and the identifier found in the *Levee_ID* field. Levee profile information is stored in the individual levee table in the field headings *Station* and *Elevation*. *Station* is the distance from the beginning of the levee to the specified-point *Elevation*. (Therefore, if the levee is constructed from upstream to downstream, the river stationing will equal zero at the upstream end (the beginning) and get larger moving downstream.)



The final levee profile will be created based on an interpolation of the user-specified levee profile data. **No extrapolation will occur along the levee outside of the specified elevations.**

Entering Surveyed Data

Surveyed station-elevation data may be entered by hand using standard ArcView Table tools or in a spreadsheet. To do so, first use the **Levee Elevation** tool to create a table linked to the levee alignment. Select the Levee Elevation tool and use the pointer to choose a "dummy" location along the levee. This will create an empty table for entering levee profile elevations. Enter a "dummy" elevation for the selected point.

Next, open the levee table (called "Levee"+*Levee_ID*) make the table editable by selecting **Table ⇒ Start Editing**. Select **Edit ⇒ Add Record** to add additional records in the levee table. Use the  (**Edit**) tool to enter station-elevation data. (Be sure to check the that orientation of the levee line matches that of the surveyed levee profile data.) Lastly, remove or overwrite the "dummy" record.

If entering the surveyed data using the table options in ArcView is cumbersome, open the table in a spreadsheet and enter the data.

Completing the Levee Alignment

GeoRAS requires the final levee alignment to be a 3D shapefile. Completing the levee alignment requires that elevation data is extracted. Select **GeoRAS_Util ⇒ Levee Profile Completion** to convert the 2D Levee theme to a 3D theme. If no user elevations have been specified, the elevation data will be extracted from the Terrain TIN. If, however, additional elevation data has been specified, levee elevations will be interpolated between the specified points.

Ineffective Flow Areas Theme

Ineffective flow areas may be used to identify portions of the cross section that do not actively convey flow. This theme may be readily constructed using visual cues upstream and downstream of bridges and culverts and in backwater areas

Rules!

- Ineffective flow area polygons must intersect a cross-sectional cut line exactly twice to form a "block".

Creating Ineffective Flow Areas

Select the **preRAS ⇒ Create Ineff. Flow Areas** menu item. This will create a new shapefile (default name of "inefflow.shp"), add it to the view, and make it active and editable.

Add the extents of each ineffective flow area using the  (**Draw Polygon)** tool. Click the left mouse button to begin the storage area. Left-click to add vertices to the polygon and finish the polygon by double-clicking. When finished creating the Ineffective Flow Paths theme, select **Theme ⇒ Stop Editing**.

The attribute table for the Ineffective Flow Areas Theme will have a field titled *IA_ID*. This field is required. The user can change the default identifiers using the table editing tools.

Storage Area Theme

Storage areas are used to model floodplain storage during unsteady-flow analysis. Storage areas are not reflected in the cross-sectional geometry. This theme is constructed by identifying the bounds of the storage area.

Rules!

- Storage areas must be contained within the bounds of the Terrain TIN.
- Storage areas should not overlap one another or cross sections.

Creating Storage Areas

Select the **preRAS ⇒ Create Storage Areas** menu item. This will create a new shapefile (default name of "storages.shp"), add it to the view, and make it active and editable.

Add the boundary of each storage area using the  **(Draw Polygon)** tool. Click the left mouse button to begin the storage area. Left-click to add vertices to the polygon and finish the polygon by double-clicking. When finished creating the Storage Areas theme, select **Theme ⇒ Stop Editing**.

The attribute table for the Storage Areas Theme will have a field titled *SA_ID*. This field is required. The user can change the default identifiers using the table editing tools.

Theme Attributing

Once the RAS Themes have been created, the geometric data extraction process may begin. The Stream Centerline theme needs to be completed and the cross-sectional attributes (geometric data for each cross section) need to be calculated. Note that the Stream Centerline theme must be correctly created before completing the Cross-Sectional Cut Line theme and the Cross-Sectional Cut Line theme must be completed before extracting additional data such as Manning's n values, levee positions, and ineffective flow areas.

Theme Setup

Before performing calculations on themes, the role of each theme should be specified. Select the **preRAS ⇒ Theme Setup** menu item. The dialog shown in Figure 4-9 will be invoked to allow you to specify the "Input Data" themes.

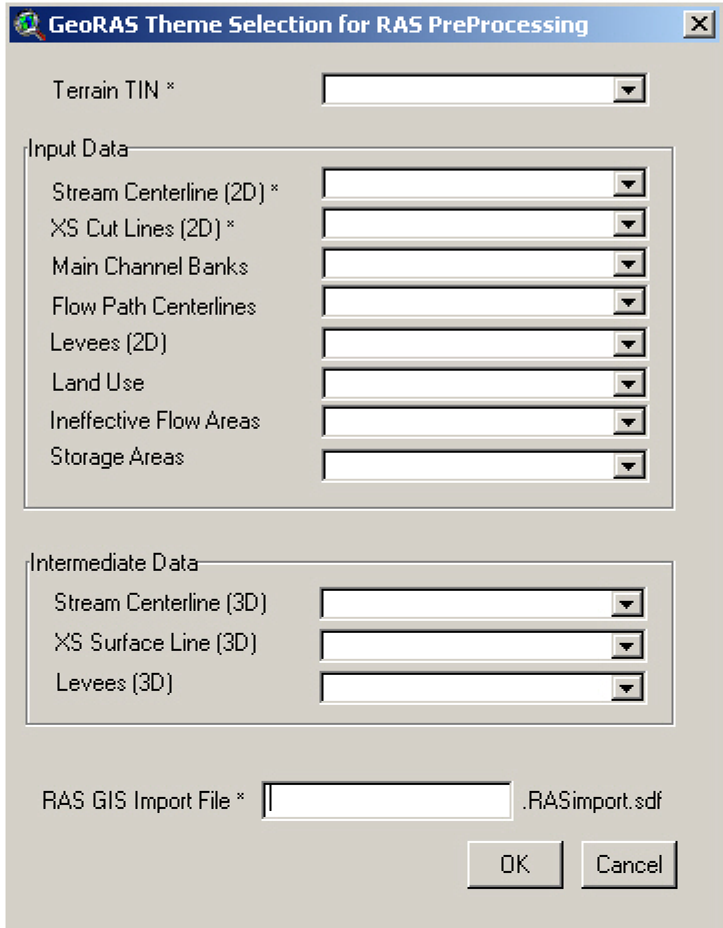


Figure 4-9. Pre-processing theme setup.

If the themes were created using the step outline on the preRAS menu, the "Input Data" field will be filled in; however, if the shapefiles were added to the project as previously created data,use the drop down lists to select the appropriate themes. The RAS GIS Import File name will need to be specified. Enter the RAS GIS Import File name and press **OK**. The extension *RASimport.sdf* will be appended to the filename.

Centerline Completion

Complete the stream centerline data by selecting the **preRAS** ⇒ **Centerline Completion** menu item. This process will establish the connectivity and orientation. The Stream Centerline is not "complete" until the **Centerline Elevations** menu item has been run to create a 3D Stream Centerline theme.

There are two processes that take place during the Centerline Completion item on the preRAS menu. Centerline Topology, establishes the connectivity and orientation (upstream and downstream ends) of the river network. The Lengths/Stations item computes the river reach lengths.

Centerline Topology

The Centerline Topology process establishes the connectivity and orientation (upstream and downstream ends) of the river network. The Stream Centerline theme must contain the *Stream_ID* and *Reach_ID* fields to complete the centerline topology. This process may be completed by selecting the **preRAS ⇒ Centerline Topology** menu item.

The Centerline Topology process will add the *from_Node* and *to_Node* fields to the Stream Centerline theme attribute table. The user must check that the node values are computed correctly. The *from_Node* indicates the upstream end of a river reach while the *to_Node* indicates the downstream end of a river reach. Therefore, a junction will be formed where three endpoints are coincident: two to-nodes and one from-node.

Lengths/Stations

This function computes the lengths along the stream centerline to the downstream and upstream most point on each river reach. The fields *from_ST* (downstream endpoint), *to_ST* (upstream endpoint), and *ArcLength* are added to the Stream Centerline theme. This step is not "required" but the fields must have data.

Centerline Elevations

The Centerline Elevations function creates a 3D shapefile from the Stream Centerline (2D) theme using the Terrain TIN to extract elevation data. The elevation data will be extracted from the TIN at every triangle edge. Stream centerline data will be written to the RAS GIS Import File from the 3D Stream Centerline shapefile.

XS Attributing

Cross section attributes are added to the Cross-Sectional Cut Line theme using the **preRAS ⇒ XS Attributing** menu item. After all the attributes (river and reach names, stationing, bank stations, and reach lengths) are appended to the Cross Section Cut Line (2D) shapefile attribute table. The 2D shapefile is then converted to a 3D shapefile by selecting **preRAS ⇒ XS Elevations**.

Stream/Reach Names

This function adds the *Stream_ID* and *Reach_ID* items to the Cross-Sectional Cut Line theme based on the intersection of the cut line with the stream centerline. The Stream Centerline theme must have the *Stream_ID* and *Reach_ID* fields. The XS_ID field is also added to the Cross Section Cut Line Theme. The XS_ID field is used to relate additional data for Manning's *n* values, levees, and ineffective flow areas.

Stationing

The stationing function adds the cross-sectional stationing based on the intersection of the cross-sectional cut lines and the stream centerline (2D). The Stream Centerline theme must have the *from_ST* and *to_ST* items. The *Station* field is added to the Cross Section Cut Line theme.

The stream stationing will be developed based on the unit system inherent to the data (usually this is based on the Terrain TIN, since it is used as the background map). Therefore, stationing can be changed to a new unit system either in HEC-RAS or in ArcView.

To change the units within ArcView make a dummy field in the Cross-Sectional Cut Line table. Highlight the dummy field and use the **Calculate** button to covert the station units. Now use the **Calculate** button to set the *Station* field data equal to the dummy field data. Changing the stationing data in ArcView is not recommend because this convolutes the data; however, this may be required for some data sets.

Bank Stations

Bank station positions for each cross section are computed from the intersection of the cross-sectional cut lines and bank station lines. Bank station positions are calculated as the percent distance along the cut line from its start in the left overbank. *L_BankP* and *R_BankP* fields are added to the Cross Section Cut Line theme for the left and right bank positions by percent, respectively. The bank station calculation method is shown in Figure 4-10.

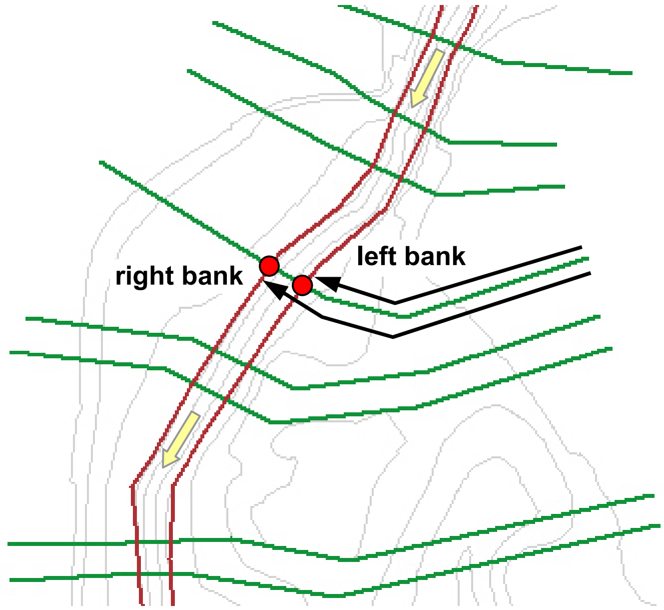


Figure 4-10. Calculation of bank station locations from bank lines and cross section cut lines.

Reach Lengths

This function adds downstream reach lengths to each cross section cut line based on the intersection of the flow path centerlines and the cut lines. *L_ReachL*, *M_ReachL*, and *R_ReachL* fields are added to the Cross Section Cut Line theme for the downstream reach lengths in the left overbank, main channel, and right overbank, respectively. The method for calculating downstream reach lengths is shown in Figure 4-11.

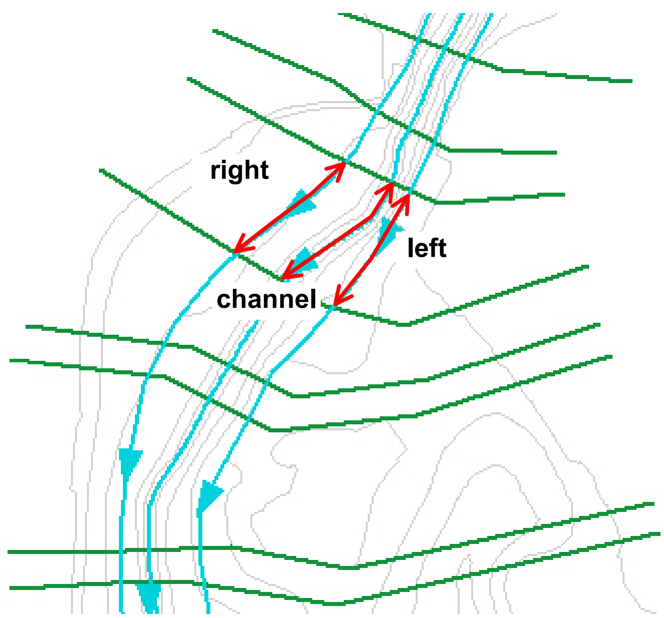


Figure 4-11. Calculation of downstream reach lengths from the flow path centerlines and cross section cut lines.

XS Elevations

The XS Elevation function creates a 3D shapefile from the Cross Section Cut Line theme. Station-elevation data is extracted from the Terrain TIN at the edge of each triangle along a cut line. The Cross Section Cut Line (2D) theme should be completely processed before converting it to a 3D shapefile. A visualization of the elevation extraction process is shown in Figure 4-12.

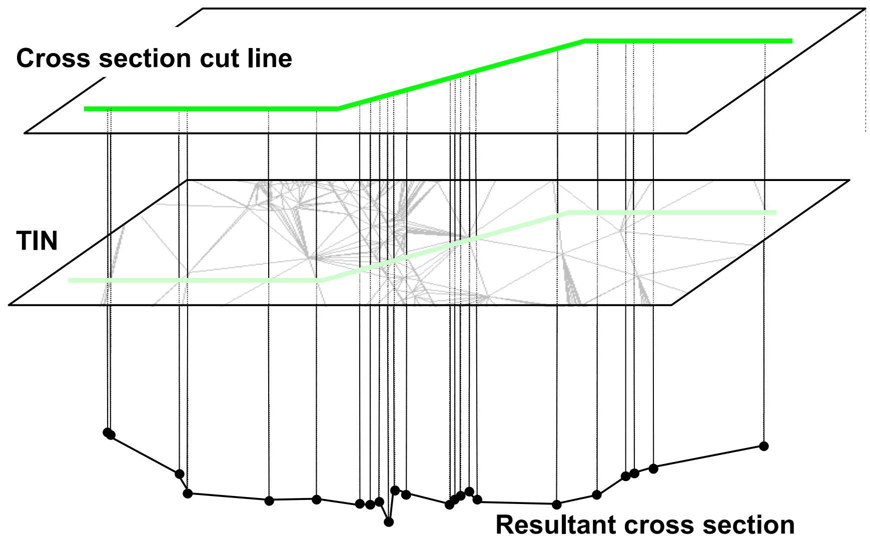


Figure 4-12. Extraction of station-elevation data from a TIN.

Manning's n Values

Manning's *n* values are extracted from the Land Use theme during this process. The Land Use theme must have an *N_va*lue field and cover the extent of all cross sections.

The field *XS_ID* in the Cross Section Cut Line theme is joined to a table of Manning's *n* values. Manning's *n* values are reported at each change along the polygon data set as a percent along the cross section cut line. The data extraction process is shown in Figure 4-13.

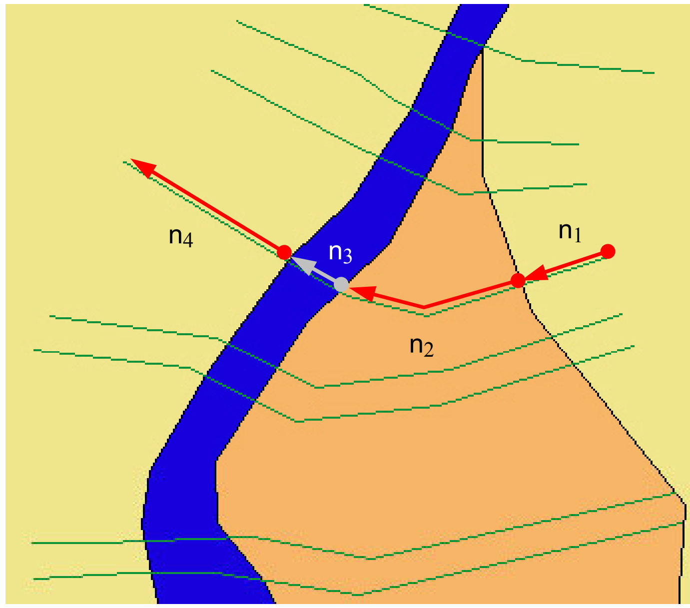


Figure 4-13. Calculation of n-value locations.

Manning's *n* value data for each cross section is reported to a table titled *Manning*. This table is comprised of three important fields: *XS_ID*, *Fraction*, and *N_Value*. *XS_ID* is used to relate the *n* values to the cut lines in the Cross-Sectional Cut Line theme. *Fraction* indicates the beginning of the *N_Value* for the given *XS_ID*.

Levee Positions

Levee positions are extracted during this process. There must be a 3D shapefile of levee profile data with a field titled *Levee_ID* in the feature attribute table to perform this function.

Levee position and elevation data is extracted from the intersection of the Cross-Sectional Cut Line theme and the Levee 3D theme. Data is reported to a table titled *Levee Positions*. The Levee Positions table will have the following fields listed below.

- *XS_ID* – identifies the cross section in the Cross Section Cut Line theme with the same identifier.
- *Levee_ID* – identifies the levee.
- *Position* – reports the position of intersection of the levee and cross section as a fraction from the beginning of the cross section.
- *GrndElev* – reports the ground elevation as extracted from the Terrain TIN at the levee position.
- *Elev* – reports the top-of-levee elevation at the given *Position* for the *Levee_ID*.

Ineffective Flow Areas

Ineffective flow area data is extracted during this process for each cross –sectional cut line. An Ineffective Flow Area polygon theme must be present for this function to work.

Ineffective flow area data are extracted based on the intersection of the Cross Section Cut Line theme and the Ineffective Flow Area theme. Data are reported in "blocks" to a table titled *Ineffective Flow Areas* indicating the beginning and ending locations for each ineffective area. The Ineffective Flow Areas table will have the following fields listed below.

- *XS_ID* – identifies the cross section in the Cross Section Cut Line theme with the same identifier.
- *IA_ID* – identifies the ineffective flow area.
- *BegPct* – reports the beginning position of intersection of the ineffective flow area and cross section as a fraction from the beginning of the cross section.
- *EndPct* – reports the ending position of intersection of the ineffective flow area and cross section as a fraction from the beginning of the cross section.
- *BegElev* – reports the ground elevation as extracted from the Terrain TIN at the *BegPct*.
- *EndElev* – reports the ground elevation as extracted from the Terrain TIN at the *EndPct*.
- *UserElev* – indicates the user-specified elevation to turn the ineffective flow option off.

The *UserElev* field allows the user to specify a specific elevation for turning the ineffective flow block off in HEC-RAS. If the user does not specify an elevation, the larger of *EndPct* and *BegPct* will be used as the default trigger elevation.

Storage Areas

Storage area data are extracted for each storage area based on the Terrain TIN. There are two main components to the process: extraction of the elevation data points in the area of the TIN and calculation of the Elevation-Volume data. After performing the data extraction, the 2D Storage Area theme will be converted to a 3D theme. This *function works on the selected set* of storage areas thereby allowing the user to extract elevation-volume data for each storage area individually. If no storage area is selected, elevation-volume data will be extracted for all storage areas.

Elevation Data

The extraction of the elevation data points in the Terrain TIN is only used to visualize the storage area being inundated in HEC-RAS during unsteady-flow simulation of results. A dialog will appear giving the user the choice of skipping the point extraction. Extracting the terrain data is not a required step and it is recommended that it be skipped.

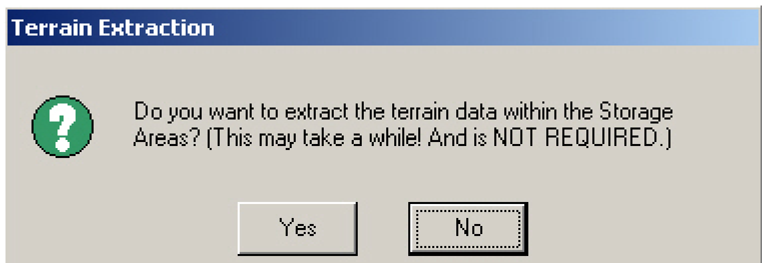


Figure 4-14. Skipping the terrain data extraction will save time.

If the terrain extraction process is not skipped, a point file of terrain points within the storage area(s) in the Terrain TIN will be created called "sa_points.shp".

Elevation-Volume Data

Elevation-volume data will be computed for each storage area based on the values in the Storage Area attribute table. The fields in the Storage Area attribute table are listed below.

- *SA_ID* – uniquely identifies the storage area.
- *MinElev* – reports the minimum terrain elevation within *SA_ID*. Elevation-volume data will be calculated from *MinElev* to *MaxElev*.
- *MaxElev* – reports the maximum terrain elevation within *SA_ID*. Elevation-volume data will be calculated from *MinElev* to *MaxElev*.
- *UserElev* – allows the user to specify a maximum elevation for calculating the elevation-volume data. *UserElev* overrides *MaxElev*.

Elevation volume data will be calculated for elevations ranging from the *MinElev* to the *MaxElev*. To extend the upper end of the elevation-volume rating curve, a user-specified elevation may be entered in the *UserElev* field to override the *MaxElev* calculated.

Elevation-volume data is reported for each storage area to a separate table titled "E-V for Storage *SA_ID*". Each table will have Elevation-Volume data between the elevations of *MinElev* and *MaxElev*. Units will be the same as the terrain data.

Elevation-volume calculations are performed at different elevation "slices" within each storage area (this assumes a "level pool" within the storage area). Ten incremental elevations are considered. Volume calculations are performed on a gridded basis with the grid-cell size a function of total storage area being considered.

Generating the RAS GIS Import File

To generate the RAS GIS Import File, the 3D Stream Centerline and Cross Section Surface Line (3D) shapefile must be created from the RAS Themes. Geometric data from the two 3D shapefiles is written to the RAS GIS Export File. The geometric data includes: river, reach, and station identifiers; cross-section cut lines; cross-section surface lines; main channel bank stations; downstream reach lengths for the left overbank, main channel; and right overbank. Additional data for Manning's n values, levees, ineffective flow areas, and storage areas may also be written to the geometric data file.

Before writing the RAS GIS Import File, select the **preRAS ⇒ Theme Setup** menu item. In the Theme Setup dialog, check that the Intermediate Data files (3D shapefiles) are correct, the correct Terrain TIN is listed, and that the RAS GIS Import File name is specified correctly. Press **OK** to save settings and dismiss the setup window.

Generate RAS GIS File

To write the RAS GIS Import File, select the **preRAS ⇒ Generate RAS GIS Import File** menu item. Header, stream network, and cross section information is written to the import file in a specific data exchange format readily importable to HEC-RAS. For a more detailed discussion of the GIS data exchange file format, refer to Appendix B. The Generate RAS GIS Import menu item performs the three tasks of Header Export, Centerline Export, and XS Export menu items.

Header Export

The Header Export menu item generates the header section for the RAS GIS Import File. It uses the 3D Stream Centerline, Cross Section Surface Line, and Terrain TIN themes to generate the header information.

Projection and unit parameters are taken from the Terrain TIN. If the TIN's projection parameters are missing (TIN's *.prj* file) the user will be asked to specify the unit type (METRIC or US CUSTOMARY), while all the other projection parameters are set to "null".

Centerline Export

The Centerline Export function writes out the stream network to the import file based on the 3D Stream Centerline theme. Each river reach endpoint will be identified in the file separately. The stream centerline coordinates (x,y,z) are reported, including the distance to the downstream endpoint.

XS Export

The XS Export menu item writes out the geometric data for each cross section. Geometric data reported includes: river and reach identifiers, cross section stationing, bank station locations, downstream reach lengths, cross section cut line coordinates (x, y), and cross section surface line coordinates (x, y, z), Manning's *n* values, levee data, and infective flow data.

Storage Area Export

The Storage Area Export menu item writes out the geometric data for each storage area. The geospatial coordinates for each storage area in the Storage Area shapefile will be written out. However, elevation-volume data will only be written for those storage areas that have corresponding elevation-volume data table. A dialog will report the results to the user if there is not an elevation-volume data table for each storage area (see Figure 4-15). You will have to complete this data in HEC-RAS, however, if the storage area is connected to the system.

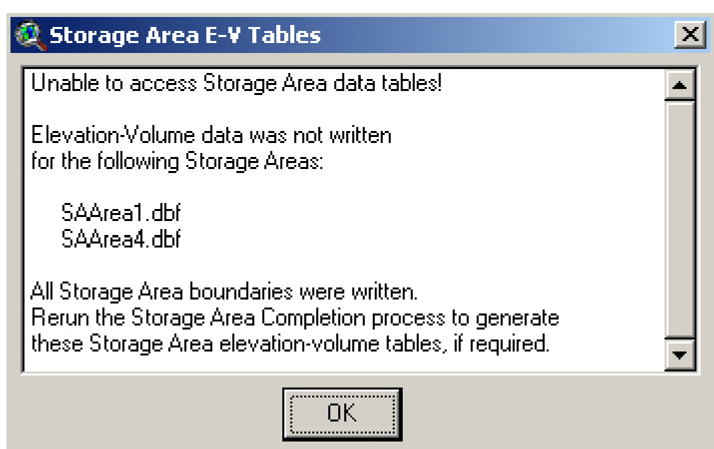


Figure 4-15. Status window will inform the user of missing elevation-volume data tables.

CHAPTER 5

Generating GIS Data from HEC-RAS Results

HEC-GeoRAS facilitates the generation of GIS themes from exported HEC-RAS simulation results. Floodplain delineation and water depth themes may be created from exported cross-sectional water surface elevations using HEC-GeoRAS. Velocity themes may also be generated.

Chapter 5 discusses the processing of exported HEC-RAS results using HEC-GeoRAS.

Contents

- Importing a RAS GIS Export File
- Processing Water Surface Elevation Data
- Processing Velocity Data

Importing a RAS GIS Export File

Importing a RAS GIS Export File requires two steps. The user must identify the export file and specify the location to store results to pre-process the raw data file. These steps are performed using the Theme Setup and Read RAS GIS Export File items on the postRAS menu.

Theme Setup

Select the **postRAS ⇒ Theme Setup** menu item. This will invoke the dialog shown in Figure 5-1, which allows the user to specify the RAS GIS Export File, Terrain TIN, Output Directory, and Rasterization Cell Size.

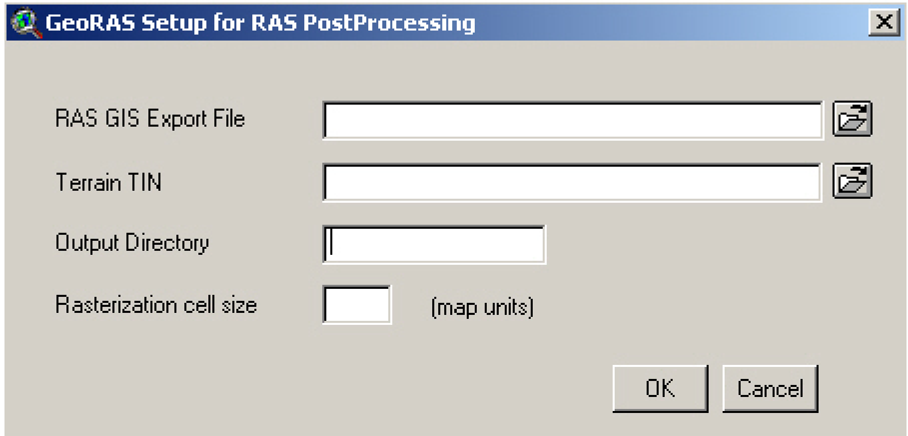
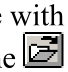


Figure 5-1. Theme setup for GeoRAS post-processing.

Select the RAS GIS Export File using the  button. HEC-RAS writes the export file with the *RASexport.sdf* file extension. Select the Terrain TIN using the  button.

Specify the Output Directory name. This the subdirectory, NOT the entire pathname. All post-processing GIS data sets will be written to the Output Directory. The path name of the Output Directory will be the name specified appended to the pathname of the location of the ArcView project file. Use a short (rather than long), meaningful Output Directory name as it will be used for naming several of the GIS themes created later. Spaces are not allowed in the Output Directory name (or the entire directory pathname).

Enter the Rasterization Cell Size. This cell size will be used in post-processing to rasterize the Terrain TIN and resulting TINs for grid cell computations (floodplain delineation, flood depth grids, and velocity grids). The smaller the cell size, the longer the processing time, but depending on the resolution of the Terrain TIN, the more accurate spatial location of the floodplain delineation. The Rasterization Cell Size should be selected based on the resolution of the Terrain TIN. As a practical consideration, start with a larger cell size and evaluate the resulting floodplain delineation and processing time. Refine the cell size during future delineations to improve the resulting floodplain boundary.

Read RAS GIS Export File

Once the post-processing theme setup is complete, RAS results can be read into the GIS. Select the **postRAS ⇒ Read RAS GIS Export File** menu item. This function will read the RAS results and create base data for GIS post-processing. The initial base themes created include: stream network, cross-sectional cut lines, cross-sectional surface lines, banks station lines, water surface profile bounding polygons, and velocity mass points.

Stream Network

A stream network theme is created from the RAS GIS Export File. It will identify the location of the stream centerline as represented in HEC-RAS and have the River and Reach names. The stream network shapefile will be named based on the concatenation of the Output Directory name and "_SN". This theme is not used during post-processing

Cross-Sectional Cut Lines

A cross-sectional cut line theme will be created based on the cross-sectional alignment in RAS during simulation. The cross-sectional cut line theme will include the stream, reach, and station identifiers for each cross section location. Water surface elevations for each flood event are exported at each cross section including whether or not the cross section was interpolated in HEC-RAS. The cross-sectional cut line shapefile will be named based on the concatenation of the Output Directory and "_XS". This theme will be used to create the water surface TIN for inundation mapping.

Cross-Sectional Surface Lines

A 3D shapefile of cross sections will be created if the cross section surface line data is present in the RAS GIS Export File. It will have the attributes of the cross-sectional cut line theme. The cross-sectional surface line shapefile will be named based on the concatenation of the Output Directory and "_XS3D". This theme is not used in post-processing.

Bank Stations

If the bank station data is present, a line theme of bank station locations will be created. The bank line shapefile will be named based on the concatenation of the Output Directory and "_Banks". This theme is not used in post-processing

Bounding Polygons

Bounding polygon shapefiles will be created for each water surface profile exported. The bounding polygon data defines the RAS model extent, thereby limiting the edge of the water surface to the end of cross sections, levees, and bridge and culvert openings. Each bounding polygon shapefile name will be a concatenation of "bp" and the water surface profile name. A "w" will be added to the water surface profile name if it begins with a numeric character.

Velocity Mass Points

If velocity data is present, a point theme of velocity mass points will be created. A separate theme will be created for each water surface profile exported. The shapefile names will be a concatenation of "vp" and the water surface profile name.

Processing Water Surface Elevation Data

Water surface elevations are written to the RAS GIS Export File at each cross section for each flood event. This water surface data in conjunction with the terrain elevation data is used for floodplain delineation and determining water surface depths. Inundation mapping may be performed for **up to 10 water surface profiles** per GeoRAS project (assuming no velocity TINs will be created). (ArcView is limited in the number of TINs that can be added to a project.) For additional water surface profile data or to analyze velocity data, create additional ArcView projects.

Water Surface TIN Generation

The first step in the delineation process creates a water surface TIN from the water surface elevations attached to each cross section. To build the water surface TIN, select the **postRAS ⇒ WS TIN Generation** menu item. This invokes a dialog allowing the user to chose which water surface profile data to process.

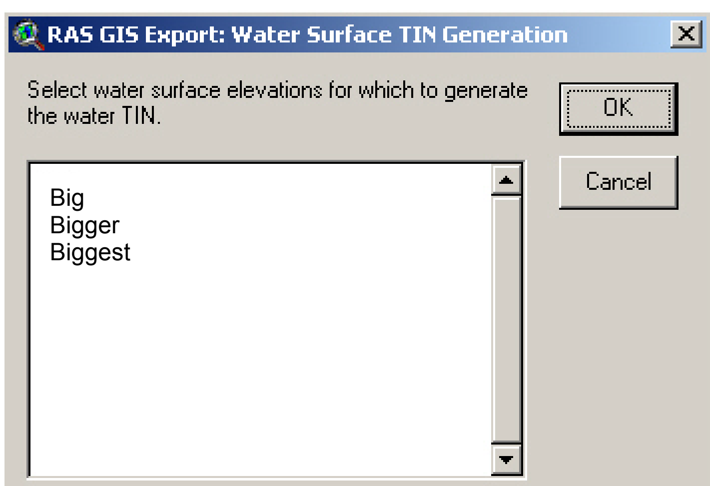


Figure 5-2. Select the water suface profiles to process.

Hold down the SHIFT key while selecting profile to select more than one. Once the profile(s) have been selected, press the OK button. A water surface TIN for each selected profile will be created. An example water surface TIN is shown in Figure 5-3.

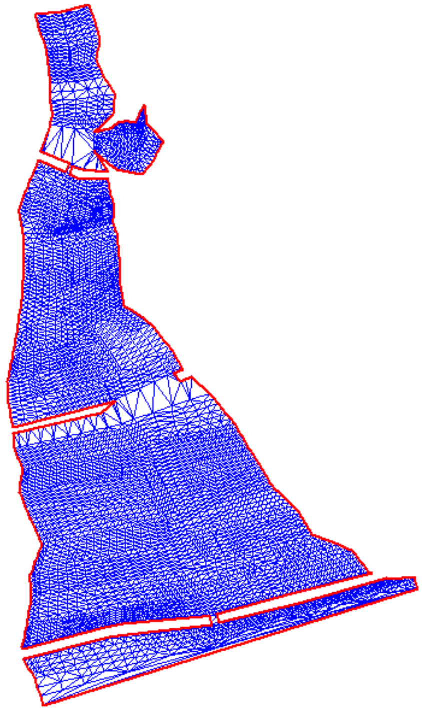


Figure 5-3. Example water surface TIN clipped by a bounding polygon.

The water surface TIN is created irrespective of the Terrain TIN and is clipped by the bounding polygon. The bounding polygon limits the water surface to the areas as modeled by HEC-RAS and should be scrutinized around meandering portions of the river model. The water surface TINs created will be named as a concatenation of "wstin" and the water surface profile name.

Floodplain Delineation

Floodplain delineation is performed using the **postRAS ⇒ Floodplain Delineation** menu item.

Rasterization of the water surface TIN and Terrain TIN is the next process. The grids are created using the Rasterization Cell Size specified in the post-processing Theme Setup dialog. The floodplain is then delineated where the water surface elevations are higher than the terrain elevations or the edge of the water surface grid is limited by the bounding polygon, as shown in Figure 5-4.

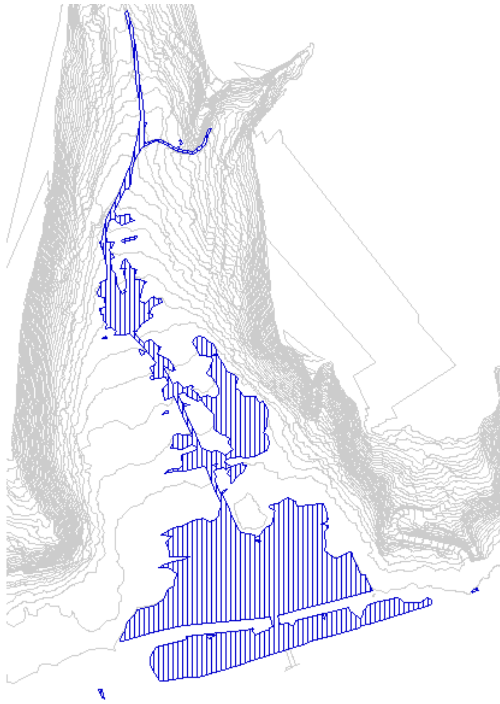


Figure 5-4. Example floodplain delineation with terrrain contours.

The same rasterized water surface TIN and Terrain TIN are subtracted to create a water depth grid. An example grid of water surface depths is shown in Figure 5-5. If Spatial Analyst is loaded (Spatial Analyst is not required, although it is recommended), the depth grid will be named from a concatenation of “gd” and the water surface profile name. Otherwise an intermediate point theme matching the computational grid layout will be created and named with the concatenation “pd” and the water surface profile name.

Floodplain delineation results should be carefully examined. Spurious ponds may be present and should be deleted in the GIS or modeled behind levees. Inappropriately placed cross sections may result in bounding polygon data incorrectly limiting the floodplain. The floodplain delineation process in GeoRAS is an iterative process that should be used to refine the hydraulic model in HEC-RAS.

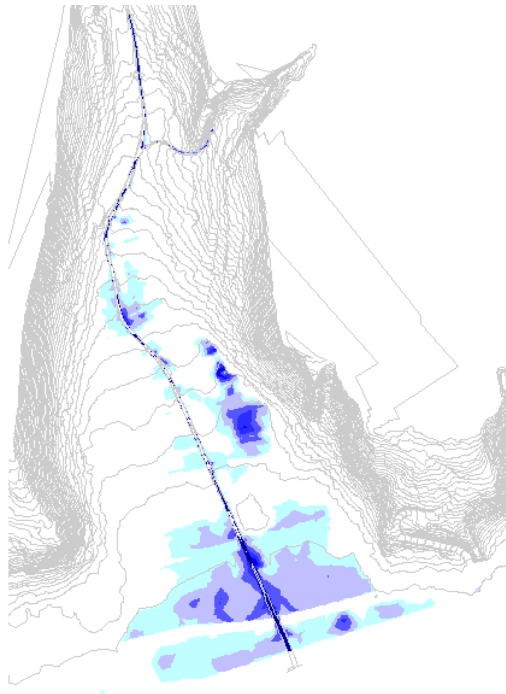


Figure 5-5. Example depth grids displayed with terrain contours.

Processing Velocity Data

Velocity data are written to the RAS GIS Export File at each cross section for each flood event. It is important to consider that velocity results generated from HEC-RAS simulations are the result of a one-dimensional hydraulic model.

Velocity TIN Generation

Select the **postRAS ⇒ Velocity TIN Generation** menu item. This process builds a TIN from the velocity mass point shapefile created in the Read RAS Import File process. The TIN building process for the velocity TIN does not follow any hydraulic rules. Triangulation (and therefore interpolation) is base purely on the spatial layout of the mass points. **Results must be carefully scrutinized.**

Velocity Grid Generation

Select the **postRAS ⇒ Velocity Grid Generation** menu item. This process will create a grid of velocities from the velocity TIN based on the Rasterization Cell Size input in the post-processing theme setup dialog. An example velocity grid is shown in Figure 5-6.

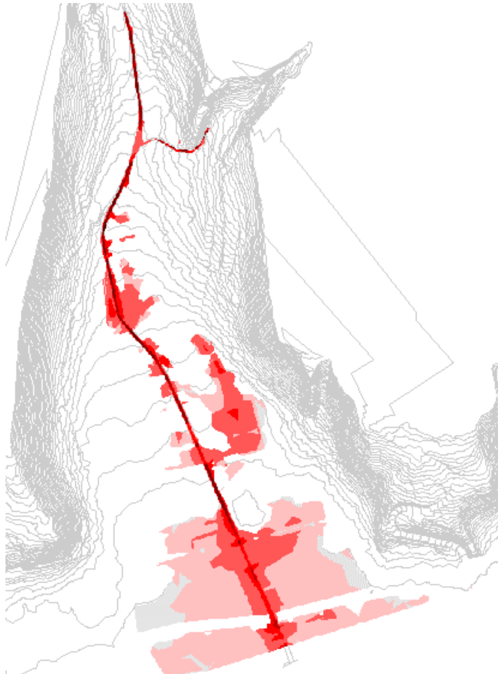


Figure 5-6. Example velocity grid displayed with terrain contours.

Velocity results must be carefully scrutinized and treated with increasing skepticism as they get farther from the cross section. Further, incorrect results may arise dictating hydraulic model refinement.

CHAPTER 6

Example Application - Wailupe River

This chapter provides an example application of how to use the HEC-GeoRAS extension in ArcView GIS for supporting hydraulic model development and analysis with HEC-RAS. This will be a step by step procedure of how to develop geometric data for import into HEC-RAS and how to develop GIS data sets from exported results from HEC-RAS simulations.

The example demonstrated is for the Wailupe River, HI, where a TIN exists for the river system. **The figures used may not be hydraulically accurate and are intended for demonstration purposes only**. Chapters 3-5 provide more detailed discussion of the steps performed in this example.

Contents

Loading HEC-GeoRAS

Start ArcView to begin. Load the HEC-GeoRAS extension by selecting **File** ⇒ **Extensions…** menu item from the main ArcView interface. Activate the HEC-GeoRAS extension by placing a check in the corresponding checkbox. Do the same for 3D Analyst and the Spatial Analyst extension, if available.

Starting a New Project

Before continuing, decide on the directory where the GIS data will be stored. If the directory does not exist, create it using a file manager. For this example, the project directory is "**Wailupe**".

Save the project to the project directory by selecting **File** ⇒ **Save Project**. In the browser that appears, navigate to the project directory, enter the project name ("**Wailupe**"), and press the **OK** button.

Make sure that the *Project Win*dow (titled "**wailupe.apr**") is active and select **Project** ⇒ **Properties**. Set the Work Directory in the Project Properties window (see Figure 6-1) to the project directory established previously. This insures that data sets created by default ArcView procedures will be stored in the same place as those created by GeoRAS.

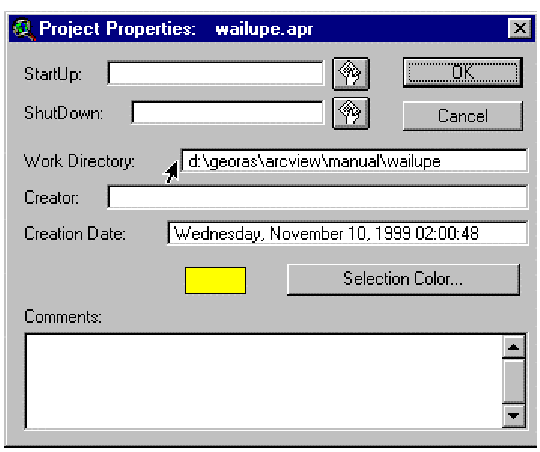


Figure 6-1. Define the "Work Directory" to establish the default location for saving data in ArcView.

From the *Project Window*, select the *View* document and press the **New** button. Make the view (**View1**) active by clicking in the view's window.

Creating Contours from a TIN

Load the Terrain TIN using the **View** ⇒ **Add Theme** menu item. Use the "Data Source Types" selection list to select TIN Data Source as shown in Figure 6-2. If the TIN is stored in the Project Directory it will be listed. Otherwise navigate to the correct directory. Select the Terrain TIN.

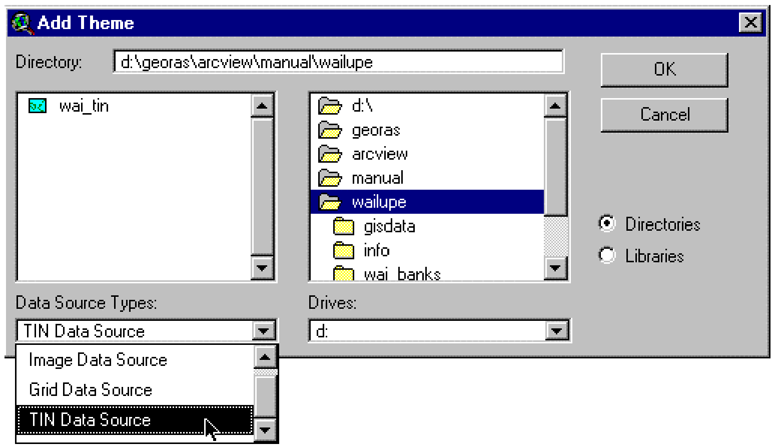


Figure 6-2. Use the "Data Source Types" selection list on the Add Theme dialog.

Create contours from the Terrain TIN by selecting **Surface** ⇒ **Create Contours**. You will be prompted to enter the contour interval. Use the default (10) and press **OK**. The contour theme will be added to the view's *table of contents*.

Make the contours visible by placing a check in the corresponding checkbox. If the contours do not provide adequate definition, generate a new theme using a smaller contour interval.

Creating RAS Themes

In this next section you will create and edit a series of themes collectively referred to as the RAS Themes. The RAS Themes are created to extract geometric data for hydraulic analysis. These five themes are the Stream Centerline, Banks, Flow Path Centerlines, Cross Section Cut Lines themes, and Land Use themes.

Stream Centerline

The Stream Centerline theme is used to establish the river reach network.

Make the current view (View1) active. The GeoRAS menus, buttons, and tools will be available from the ArcView interface. Select **preRAS ⇒ Create Stream Centerline** menu item. The dialog box shown in Figure 6-3 will appear. Specify a name for the new shapefile and destination directory and press **OK**.

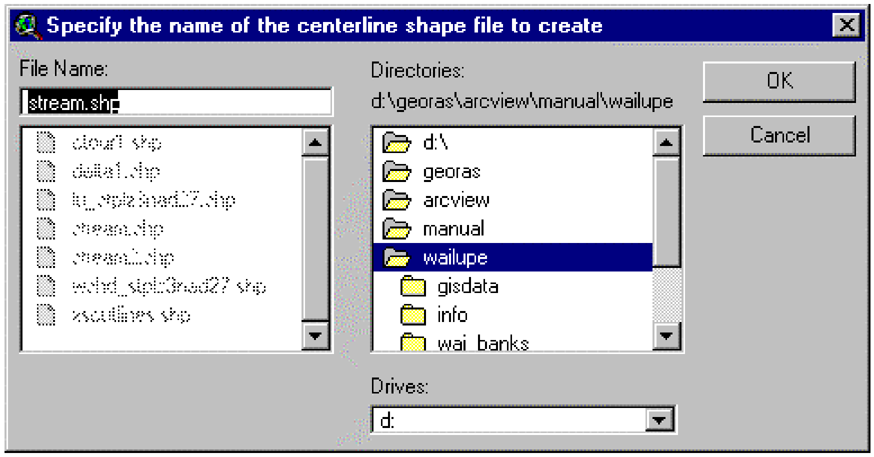


Figure 6-3. The default name for the Stream Centerline theme is "stream."

The Stream Centerline theme shapefile will be added to the view and will be active and editable. You are now ready to create the two river, three-reach river network shown in Figure 6-4.

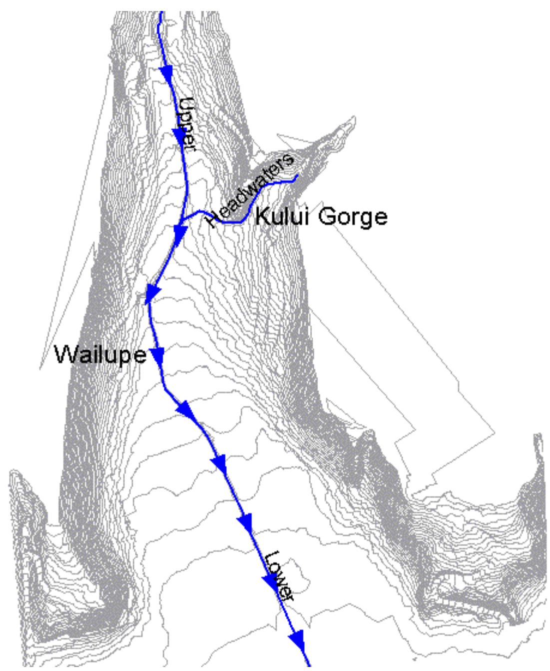
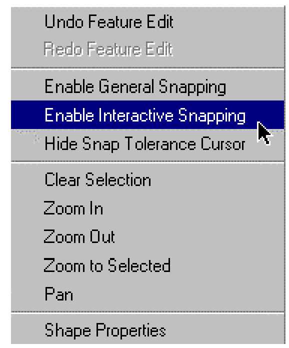


Figure 6-4. River and reach network for the Wailupe River.

Activate the (**Zoom In**) tool and zoom into the upper portion of the watershed. Next, activate the (**Draw Line**) tool. Begin the first reach by placing the cursor at the upstream most point and left clicking. This creates the upstream endpoint. Begin creating the reach in the downstream direction by left clicking to add vertices.

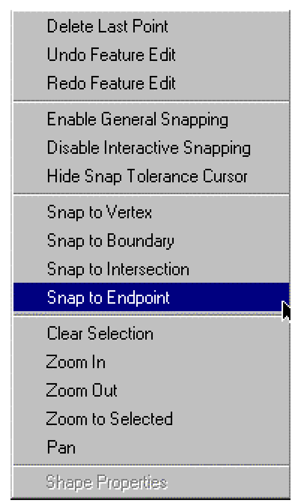
If you run out of digitizing space while creating the river reach, you can pan on the fly. While still in the Draw Line mode, move the cursor to the portion of the window you want to see, right click over the display window, and select **Pan** from the popup window.

When you reach the confluence of the two reaches, double-click to end the reach.



Before creating the next reach you should enable snapping. Right click in the display window. In the popup menu that appears, select **Enable Interactive Snapping**.

You also need to set the snapping tolerance. Activate the  (**Snap**) interactive tolerance tool. Move the cursor to the downstream endpoint of the reach you just created and draw a small circle around the endpoint using the cursor (click and hold to draw the circle, let go to finish). Now you are ready to draw the next river reach.



Pan or zoom to the upstream end of the next reach. Activate the Draw Line tool and begin drawing the reach down to the confluence. When you are ready to end the line at the junction, right click on the display window. In the popup menu that appears, select the **Snap to Endpoint** option.

The cursor will change from the standard drawing cross-hairs to a pointer with a circle. The circle defines the interactive snapping tolerance distance. Place the cursor at the junction and double click to end the line.

With the Draw Line tool still active create the third reach. First, right click over the display window and select Snap to Endpoint. (This will snap the first point you place at the junction.) Move near (within the snap tolerance distance) and click to start the reach. The line will automatically snap to the intersection. Use the mouse to draw the remainder of the reach, using the pan and zoom tools as required.

When finished drawing the river reach network, select the **Theme ⇒ Stop Editing** menu item. Use the (**Zoom to Active Theme**) button to zoom to the full extent of the Stream Centerline theme.

Now label each river reach with an identifier. Activate the (**River Reach ID**) tool. Use the cursor in the display window to select a river reach. Upon selection, the dialog shown in Figure 6-5 will appear. Enter the River Name and Reach Name for each reach. In this example the ***Wailupe* River** has and ***Upper*** and ***Lower*** reach and the ***Kului Gorge*** is a ***Tributary*** stream.

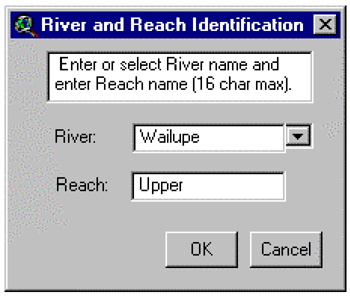


Figure 6-5. Label each river reach with a unique name.

Banks

The Banks theme is used for identify the main channel conveyance area from that of the overbank floodplain areas.

Select the **preRAS ⇒ Create Banks** menu item. The Banks theme shapefile will be created and added to the view. The theme will be active and editable.

Establish the bank station locations on either side of the channel for the Wailupe River and Kului Gorge using the **Draw Line** tool. Use the pan and zoom tools discussed earlier to navigate. Make sure that there is only one line for each bank station location. When finished select **Theme ⇒ Stop Editing** menu item. The resultant bank lines should look like those illustrated in Figure 6-6.

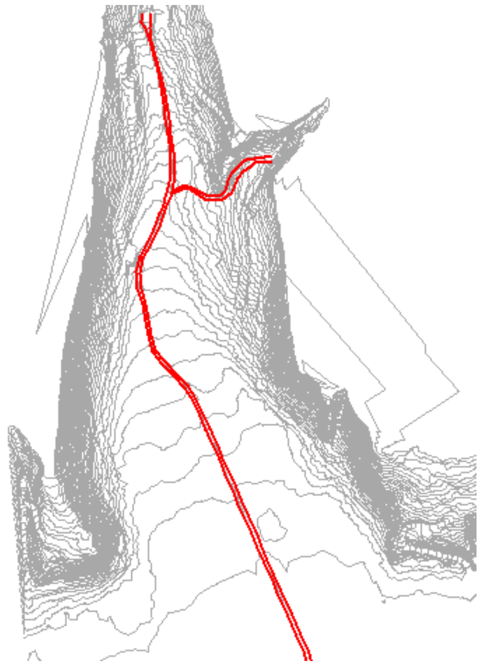


Figure 6-6. Delineation of the main channel from overbanks areas.

Flow Path Centerlines

The Flow Path Centerlines theme is used to determine downstream reach lengths between cross sections in the channel and overbanks areas.

Select the **preRAS ⇒ Create Flowpaths** menu item. Because you have already created the Stream Centerline theme, a dialog box will appear asking you if the center flow path should be copied from the Stream Centerline theme. Press **Yes** to copy the centerline.

Create flow paths in the left and right overbank for each of the rivers using the Draw Line tool. Create the flow paths in the direction of flow (from upstream to downstream) and located to indicate the center of mass of flow for a specific event. When finished, select **Theme ⇒ Stop Editing** menu item. Your flow paths should look similar to those in Figure 6-7.

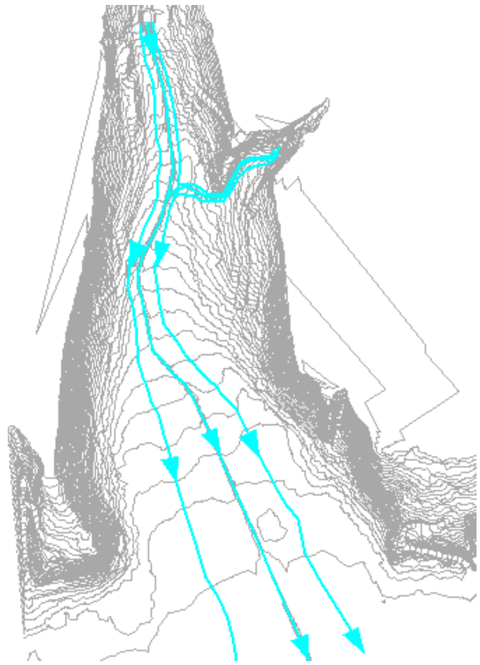


Figure 6-7. Illustration of flow path centerlines.

Now label each flow path with an identifier. Activate the F (**Label Flowpaths**) tool. Use the cursor in the display window to select a flow path. Upon selection, the dialog shown in Figure 6-8 will appear. Select from the drop down list the correct label for the left overbank, channel, and right overbank flow paths.

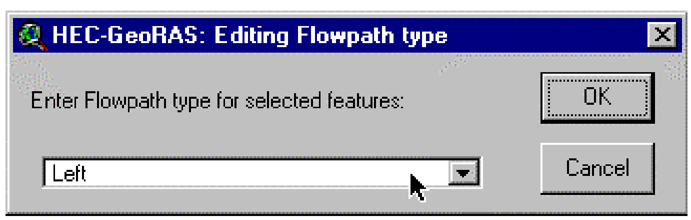


Figure 6-8. Each flow path must have an identifier of "Left"," Channel", or "Right".

Cross-Sectional Cut Lines

Cross section cut lines are used to identify the location at which cross-sectional data will be extracted from the Terrain TIN and for bank station, downstream reach length, and land use computations.

Select the **preRAS ⇒ Create Flowpaths** menu item. Use the Draw Line tool to create cross-sectional location lines. Use the mouse to drawn the cross-sectional lines from the left overbank to the right overbank perpendicular to the direction of flow. When finished, select **Theme ⇒ Stop Editing** menu item. Your cross section cut lines may look similar to those in Figure 6-9.

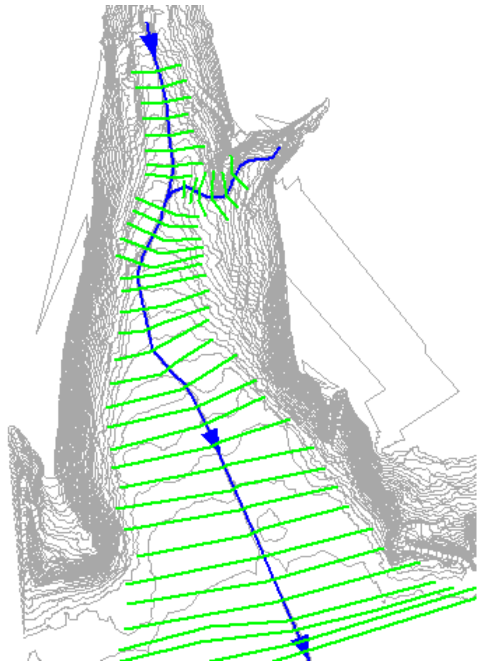


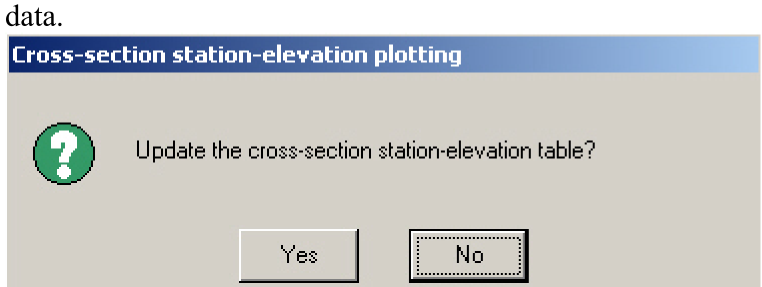
Figure 6-9. Cross section cut lines span the entire floodplain.

Previewing Cross Sections

Cross section profiles similar to that in Figure 6-10 can be previewed through the series of steps described below.

1. Select the  (**XS Plot**) tool.

2. Select **Yes** in the dialog that appear to extract the cross-sectional data.



3. Use the  cursor to select the cross section of interest.

4. The cross section will be plotted in a chart window, as shown in Figure 6-10.

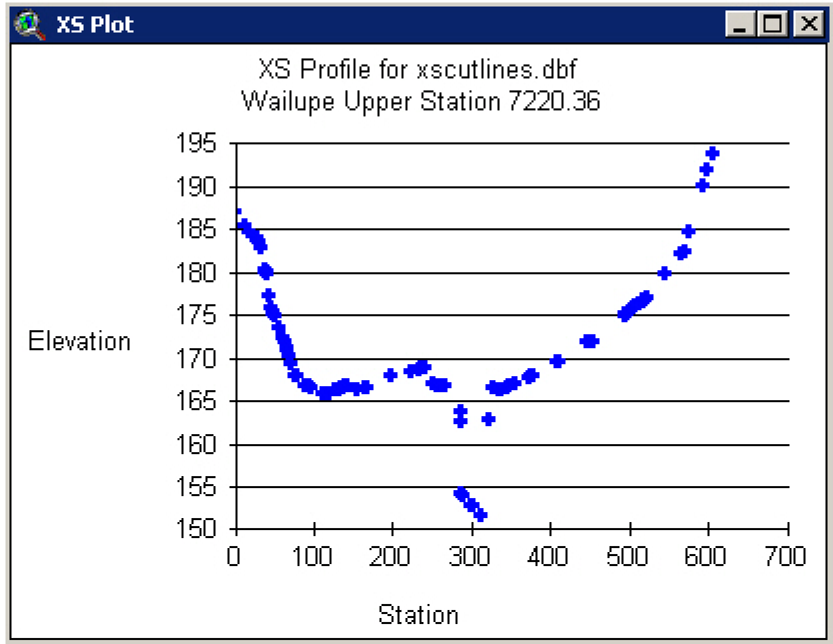


Figure 6-10. Example cross section previewed using the XS Plot tool.

Land Use

The Land Use theme is used to reference roughness coefficients for each cross section.

Make the Land Use theme active. Select the **GeoRAS_Util ⇒ Create LU-Manning table** menu item. In the dialog that is invoked, select the field that holds the land-use data values from the selection list. This will create a summary table (default name "lumanning.dbf") of land use values and create a field titled *N_value*.

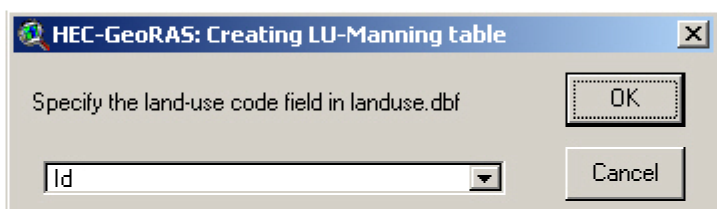
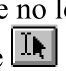


Figure 6-11. Select the land use field dialog.

From the *project* window, select the *tables* document. The name of the table will appear as an available document. Select the table and press the **Open** button. The table will open with the field names across the top shown in italics with a gray background.

Select **Table ⇒ Start Editing** to begin entering *n* values. Note that the field names are no longer in italics, indicating that the table may be edited. Use the  (**Edit Cells**) tool to edit values in the table. When finished entering *n* values, select **Table ⇒ Stop Editing**.

Select the view document used for creating the themes to access the GeoRAS menus.

Attributing RAS Themes

The theme attributing process is where the GIS performs calculations and appends the results to corresponding tables. The two themes which have data appended to their tables are the Stream Centerline and Cross Section Cut Lines themes.

Before attributing the themes make sure you have the correct themes specified. Select the **preRAS ⇒ Theme Setup** menu item. Using the drop down lists in the pre-processing dialog window, select the theme corresponding to the Terrain TIN and the "Input Data" fields. Also enter the name for the RAS GIS Import File you will create later (*RASImport.sdf* will be appended to the filename).

Stream Centerline Theme

Select the **preRAS ⇒ Centerline Completion** menu item. This will establish the connectivity and directionality of the reach network and then create a 3D shapefile by extracting elevation data from the Terrain TIN.

Stream and reach fields (*Stream_ID* and *Reach_ID*) were already present in the Stream Centerline theme table. The fields appended to the table and a short description is provided in Table 6–1.

Table 6–1. Fields appended to Stream Centerline theme table.

Field	**Description**
From_node	Integer assigned to upstream endpoint
To_node	Integer assigned to downstream endpoint
To_station	Stationing at upstream endpoint
From_station	Stationing at downstream endpoint
Arclength	Length of line defining reach

Check that each field has been added to the Stream Centerline theme table. Make the Stream Centerline (3D) theme active and press the  (**Table**) button. This will bring up the table for the active theme. Check to ensure that the fields are correctly there and that each value has been filled in.

Cross-Sectional Cut Lines Theme

Select the XS Attributing menu items. If you select the **preRAS ⇒ XS Attributing** menu item, all the functions below (and indented) it will be run. (As a general rule, only use the XS Attributing menu item on "good" data sets that have been tested using the individual menu items.) The XS Attributing item calculates the cross-sectional geometric properties for each RAS Theme. However, you should go through each individual attribute individually, following the order on the preRAS menu (Stream/Reach Names, Stationing, Banks, Flow Paths). The fields appended to the table are provided in Table 6–2.

Table 6–2 . Fields appended to the Cross Section Cut Lines theme table.

Field	Description
Stream_ID	Stream Name taken from the Stream Centerline.
Reach_ID	Reach Name taken from the Stream Centerline.
XS_ID	Cross section ID linked to LUManning table.
Station	Cross section stationing.
R_BankP	Fraction of cut line to right bank station.
L_BankP	Fraction of cut line to left bank station.
R_ReachL	Downstream reach length for right overbank.
M_ReachL	Downstream reach length for channel.
L_reachL	Downstream reach length for left overbank.

Dialog boxes will inform you if each step is successful. After all the processing is completed, however, you should check that each field has indeed been added and have reasonable values.

Make the XS Cut Lines (2D) theme active and press the **Table** button. This will bring up the table for the active theme. Check that the fields are correctly there and that each value has been filled in.

Make the view active. Select the **preRAS ⇒ XS Elevations** menu item. This will create a 3D shapefile (XS Surface Line) from the Cross-Sectional Cut Lines (2D) shapefile by extracting elevations from the Terrain TIN. The attribute table for the new 3D shapefile will be identical to 2D shapefile and the elevations.

Manning's n Values

If you have the Land Use theme completed with a field titled *N_values*, extract the estimated Manning's n values by selecting the

preRAS ⇒ XS Elevations menu item. This will create a new table of n value data for each cross section. The table is called "Manning" and will be used to write the data to the RAS GIS Import File.

Writing the RAS GIS Import File

Once you have the 3D Stream Centerline and the 3D XS Surface Line themes created, you are ready to write the RAS FIS Import File. You already specified the RAS GIS Import File name earlier, but if you wish to change it you can using the **preRAS ⇒ Theme Setup** menu item.

Select the **preRAS ⇒ Generate RAS GIS Import File** menu item. This will create the import file complete with header, stream network, and cross section information. You will be prompted, upon completion, for the name and location of the file.

Running HEC-RAS

To use HEC-RAS in concert with GeoRAS, perform the following steps:

1. Start a new project in HEC-RAS.
2. Import the RAS GIS Import File into HEC-RAS. This is accomplished from the Geometric Data editor by selecting **File ⇒ Import Geometry Data ⇒ GIS Format**. For a more complete discussion on importing geometric data, refer to the HEC-RAS User's Manual, Chapter 13.
3. Complete the hydraulic data. Hydraulic structure data such as bridges and culverts, as well as levees, blocked obstructions, or ineffective flow areas will need to be completed. Banks station data may need to be modified using the graphical cross section editor. This is available by selection **Tools ⇒ Graphical XS Edit…** menu item on the Geometric Data editor.

   The cross-sectional station-elevation data may need to be filtered down to less than 500 points. This is available by selecting **Tools ⇒ Cross Section Points Filter** menu item on the Geometric Data editor of HEC-RAS.
4. Complete the flow data and boundary conditions. Specify water surface profile names. For use with GeoRAS, avoid using a number as the first character in the profile name and using blanks.

5. Export the HEC-RAS simulation results to the RAS GIS Export File. This is accomplished by selecting **File ⇒ Export GIS Data** from the main HEC-RAS window. For a more complete discussion on exporting GIS data, refer to the HEC-RAS Users Manual, Chapter 13.

Importing the RAS GIS Export File

Once the file has been exported from HEC-RAS you can read the data into the GIS. Select the **postRAS ⇒ Theme Setup** menu item. This will invoke the dialog shown in Figure 6-12 (with empty fields). Select the RAS GIS Export File and Terrain TIN, enter the Output Directory and Rasterization Cell Size, and press **OK**. This will create a new subdirectory that contains all the post-processing results from GeoRAS.

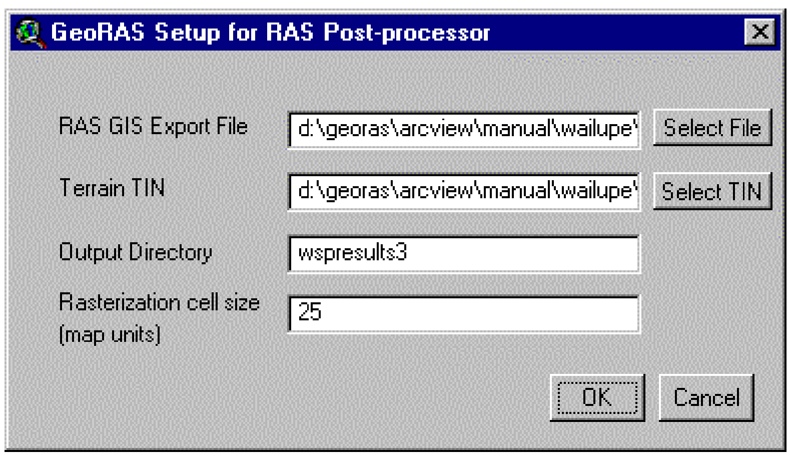


Figure 6-12. Post-processing theme setup dialog.

Next, select the **postRAS ⇒ Read RAS GIS Export File** menu item. This will read the results from the export file and create initial data sets. The stream network, cross section data, and bank station data will be read and shapefiles will automatically be generated.

The shapefile names will be a concatenation of the Output Directory and an abbreviation (_SN, _XS, _Banks). The bounding polygon data and velocity point data will be read and shapefiles will be automatically generated. Shapefile names will be a concatenation of an abbreviation (Bp, Vp) and the water surface profile name. Shapefiles created are summarized in Table 6–3.

Table 6–3. Initial post-processing shapefile names.

Shapefile	Description
…_SN	Stream network line shapefile.
…_XS	Cross section cut lines shapefile.
…_Banks	Bank line shapefile.
Vp…	Velocity point shapefile for each water surface.
Bp…	Bounding polygon shapefile for each water surface.

Generating GIS Data from RAS Results

Once the data has been read in from the RAS GIS Export File, you are ready to create water surface and velocity data sets. All the post-processing from this point forward will be using the initial data set you created in the previous step.

Water Surface TIN

Select the **postRAS ⇒ WS TIN Generation** menu item. A dialog will be invoked allowing you to select the water surface profile for which to create the water surface TIN. You may select one or many of the water surface profiles by **clicking once** on each profile. Press **OK** to begin the TIN generation process.

The water surface TIN is created from the cross-sectional cut lines theme (_XS) and the bounding polygon theme (Bp) for the respective water surface profile names. The water surface TINs created will have the water surface profile name prefixed by “Wstin” and will be added to the current view (Output Directory).

Depth Grid

Select the **postRAS ⇒ Floodplain Delineation** menu item. This time a dialog will appear allowing you to select from a list containing water surface profile names for those which have a water surface TIN (created in the previous step). You may select one or many of the water surface profiles by **clicking once** on each profile. Press **OK** to begin the floodplain delineation.

The floodplain delineation will create a polyline theme identifying the floodplain and a depth grid. The names will be the water surface profile name prefixed by “Fp” and “Gd” for the floodplain and depth grid, respectively.

Turn on the floodplain polygon by selecting the corresponding checkbox. The floodplain should look similar to that shown in Figure 6-13. Use the pan and zoom tools to scrutinize the floodplain delineation.

Next, turn on the depth grid by selecting the corresponding check box. Zoom into an interesting area and use the **(Identify)** tool tool to find water depths at various locations. An example depth grid and water depth is shown in Figure 6-14.

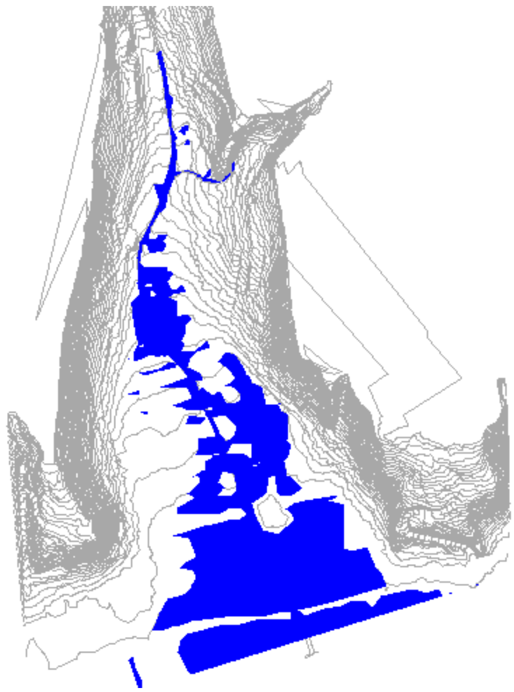


Figure 6-13. Example floodplain delineation.

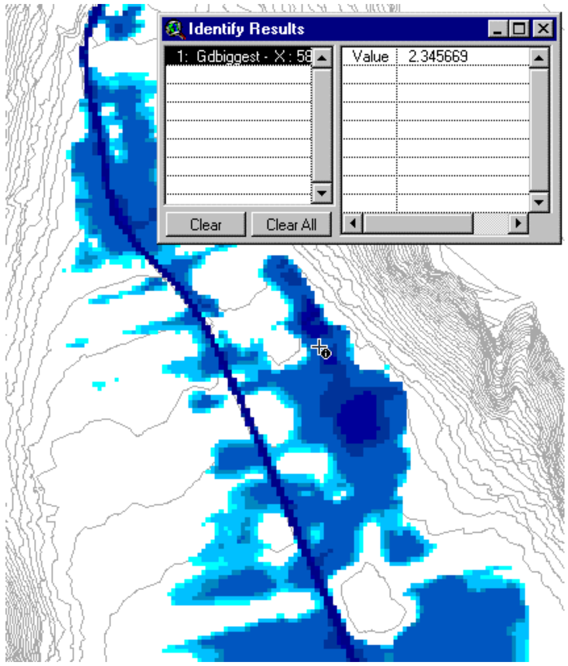


Figure 6-14. Example depth grid with identify results for water depth. Deeper water is indicated by darker blue.

Velocity TIN

Select the **postRAS ⇒ Velocity TIN Generation** menu item. This will provide a dialog that will allow you to pick from a list. The list will contain water surface profile names for which a floodplain delineation (floodplain polygon) has been performed and that have a velocity point shapefile. You may select one or many of the water surface profiles by **clicking once** on each profile. Press **OK** to begin velocity TIN generation.

The velocity TIN will have the name of the water surface profile prefixed by “Veltin” and will be added to the current view.

Velocity Grid

Select the **postRAS ⇒ Velocity Grid Generation** menu item. Velocity grids (see Figure 6-15) will be generated for from each velocity TIN.

The velocity grids will have the name of the water surface profile prefixed by “Vgd” and will be added to the current view. Display a velocity grid by selecting the corresponding checkbox. Again, pan/zoom to an interesting area and use the identify tool to find areas of high velocity.

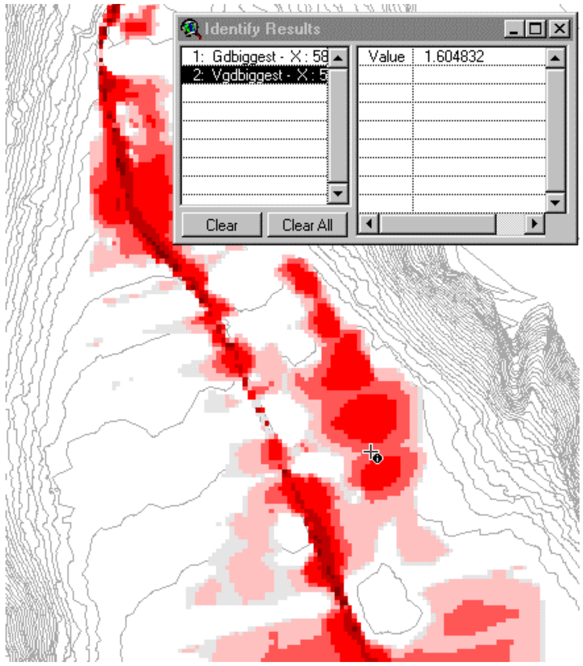


Figure 6-15. Example velocity grid. Higher velocities are indicated by darker red.

CHAPTER 7

Example Application - Baxter River

This chapter provides detailed discussion of how to use the HEC-GeoRAS extension in ArcView GIS for supporting hydraulic model development and analysis with HEC-RAS. This provodes a step-by-step procedure of how to develop geometric data for import into HEC-RAS and how to develop GIS data sets from results exported from HEC-RAS.

This example is for the fictional Baxter River that majestically meanders through Tule Town, USA. We begin our example with a TIN of the river system that incorporates detailed terrain data in both the main channel and adjacent floodplain. The detailed terrain model will be the basis for this example.

The figures used in this example are intended to demonstrate the GeoRAS process and underlying principles and *may not* be hydraulically accurate. For more discussion on the steps addressed in this example refer to Chapters 3-5.

Contents

- Loading HEC-GeoRAS
- Starting a New Project
- Creating Contours from a TIN
- Creating RAS Themes
- Attributing RAS Themes
- Generating the RAS GIS Import File
- HEC-RAS Hydraulic Analysis
- Importing the RAS GIS Export File
- Generating GIS Data from RAS Results

Loading HEC-GeoRAS

Start the ArcView GIS program. Load the HEC-GeoRAS extension by selecting the **File** ⇒ **Extensions** menu item from the main ArcView interface. Activate the HEC-GeoRAS extension by placing a check in the corresponding checkbox. Do the same for 3D Analyst extension and the Spatial Analyst extension, if available.

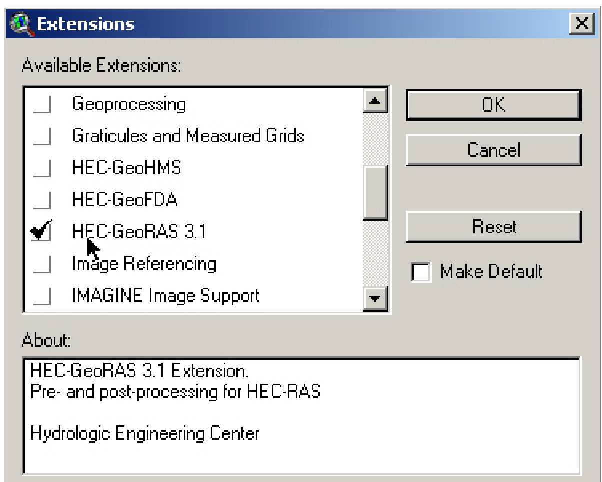


Figure 7-1. Load the HEC-GeoRAS extension by checking it on.

Starting a New Project

Before continuing through the GeoRAS data development, it is a good idea to think through the directory structure for your data. Decide on the location to store your GIS data. If the directory does not exist, create it using a file manager. Make sure there are no spaces in any of the directory pathnames! Move your Terrain TIN to an appropriate directory. For this example, the project directory has been named “Example31” (since this example will demonstrate functionality of GeoRAS 3.1).

Save the ArcView project to the project directory by selecting **File** ⇒ **Save Project**. In the browser that appears, navigate to the project directory, enter the project name (“BaxterRiver”), and press the **OK** button.

Setting the Work Directory

The Work Directory is the directory ArcView will use by default for creating data sets; therefore, any data you create using GeoRAS will by default be stored to the specified Work Directory.

Make sure that the Project Window (titled "**baxterriver.apr**") is active and select **Project** ⇒ **Properties**. Set the Work Directory in the Project Properties window to the project directory established previously (see Figure 7-2). The pathname for the Work Directory must be typed in correctly; ArcView will not create a new directory. Once you have specified the directory press the **OK** button.

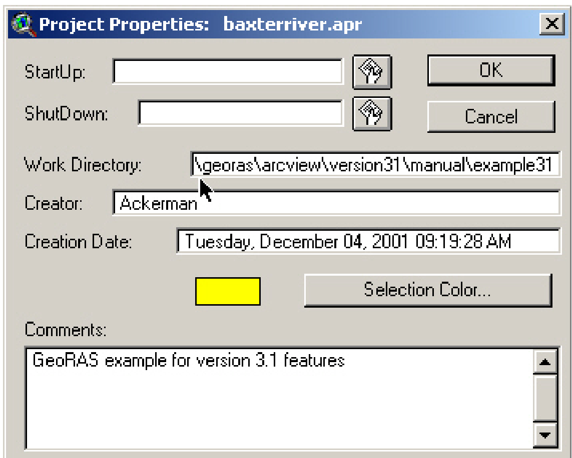


Figure 7-2. Define the Work Directory to set the default location for saving data.

From the Project Window, select the *View* document and press the **New** button (or double-click the *View* document). This will make an empty view (View 1). Make **View 1** active by clicking in the view's window. Note that the GeoRAS extension menus, buttons, and tools now show up on the ArcView interface.

You can change the name of View 1 by selecting **View** ⇒ **Properties** from the ArcView interface. As shown in Figure 7-3, the title of the view has been changed to **RAS Themes**. Other properties can be changed from the View Properties dialog, including the background color.

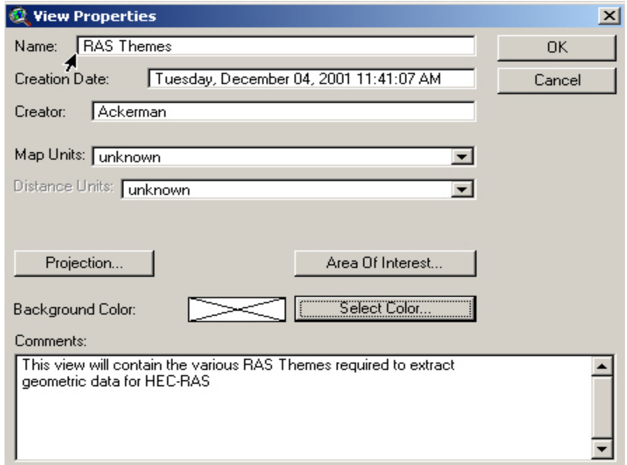


Figure 7-3. View properties dialog.

Save your newly created project be choosing **File ⇒ Save Project**. Note that what you are actually saving each time you save your project is the project's settings. You are not saving data; you are saving what windows are open, what size they are, what data is displayed, how it is displayed, etc.

Creating Contours from a TIN

Load the Terrain TIN using the **View ⇒ Add Theme** menu item. Use the "Data Source Types" selection list to select TIN Data Source as shown in Figure 7-4. If the TIN is stored in the Project Directory it will be listed. Otherwise navigate to the correct directory. Select the Terrain TIN ("**baxtertin**").

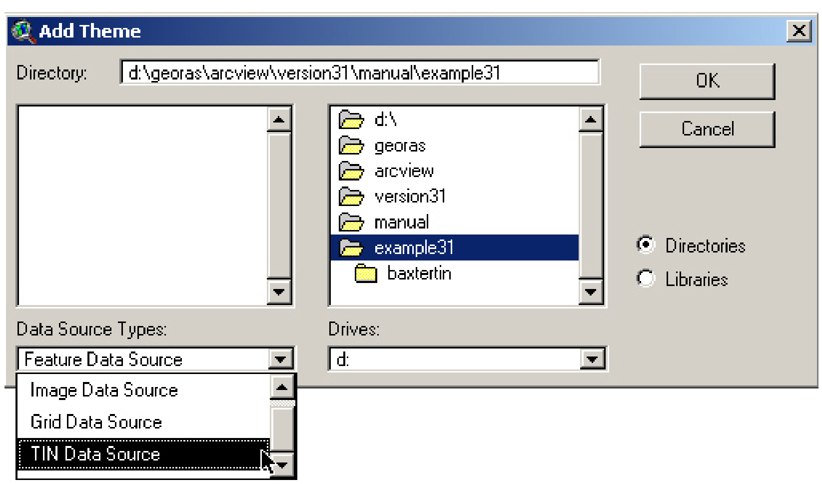


Figure 7-4. Select the Data Source Type to add a TIN.

Create contours from the Terrain TIN by selecting **Surface ⇒ Create Contours**. You will be prompted to enter the contour interval. Use the default (10) and press **OK**. The contour theme will be added to the view's *table of contents*.

Make the contours visible by placing a check in the corresponding checkbox. If the contours do not provide adequate definition, generate a new theme using a smaller contour interval.

Creating RAS Themes

In this next section, you will create and edit a series of themes collectively referred to as the RAS Themes. The RAS Themes are the basis for the geometric data extracted in the GIS for hydraulic analysis in HEC-RAS. The RAS Themes include: Stream Centerline, Banks, Flow Paths Centerlines, Cross-Sectional Cut Lines, Land Use, Levee Alignments, Ineffective Flow Areas, and Storage Areas.

The RAS Themes will be used in the following section titled *Attributing RAS Themes* to extract geometric data as attributes for import into HEC-RAS.

Stream Centerline

The stream centerline is used to establish the river reach network. The stream network must be digitized in the direction of flow with reach endpoints coincident at junctions.

Make the current view ("BaxterRiver") active. The GeoRAS menus, butons, and tools are now available from the ArcView interface. Select the **preRAS ⇒ Create Stream Centerline** menu item. A file browser will appear with the default name of "**stream.shp**" for the Stream Centerline shapefile. Change the name as desired, make sure the file will be save to the correct directory, and press **OK**.

A blank Stream Centerline theme will be added to the view and will be active and editable, allowing you to create the stream network. The two river, three reach network for Baxter River system is shown in Figure 7-5.

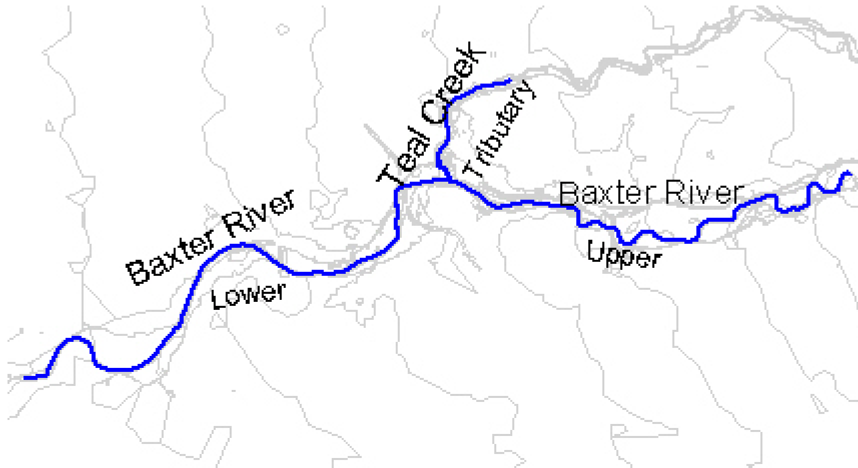


Figure 7-5. Stream network for the Baxter River.

Based Figure 7-5 you have an idea of what the river system looks like: the Baxter River flows from the Upper to Lower reach, with a tributary dividing the two reaches. We will start by digitizing the stream centerline.

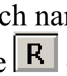
Activate the **Zoom In** tool and zoom into the upper portion of the watershed (zoom in so that the channel is well defined by the contours). If the channel is not well defined, you may have to use the Terrain TIN for visualization or create a new set of contours. Next, activate the **Draw Line** tool.

Begin digitizing the upper reach by placing the cursor at the upstream most point of the study area and left-clicking. This creates the upstream endpoint. Continue the reach downstream by left-clicking to add vertices.

If you run out of viewable space while digitizing, you can pan (or zoom) on the fly. To pan, move the cursor to the edge of the view window (where you want to move to) and right-click. In the popup menu that appears, select **Pan** (or choose one of the zoom options).

Continue creating the stream network. Double-click to finish a reach. For the Baxter River there is one junction where the Teal Creek enters. This means we will digitize three reaches with endpoints at the junction. Go ahead and finish digitizing all the reaches, we will create the junction after the river network skeleton has been digitized. (See the Chapter 6 Example to create the junction on the fly, using interactive snapping.)

River and Reach Naming

Each river must have a unique reach name and each tributary must have a unique river name. Use the 

(**River Reach ID**) tool to give each river and reach a name.

Click on the **River Reach ID** tool to make it active. With the labeling cursor, select each river reach to name. The River and Reach Name dialog will appear allowing you to enter the river and reach name. In this example the ***Baxter River*** has an ***Upper*** and ***Lower*** reach and ***Teal Creek*** is a ***Tributary***.

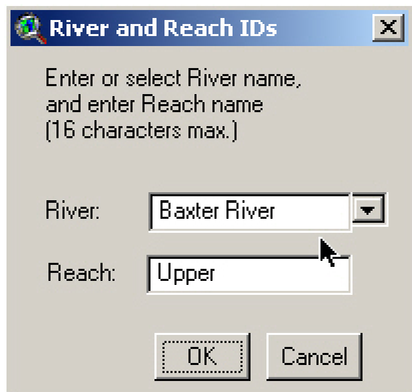


Figure 7-6. River and Reach labeling dialog.

After labeling each River Reach, look at the Stream Centerline attribute table. To open the table, activate the Stream Centerline theme and press the Open Table button. Note that there are two fields in the Stream Centerline table: *Stream_ID* and *Reach_ID*. Under each of fields will be the River Name and Reach Name for each river reach. More fields will be added later to verify stream network connectivity.

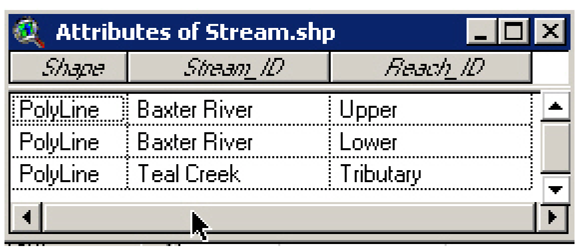
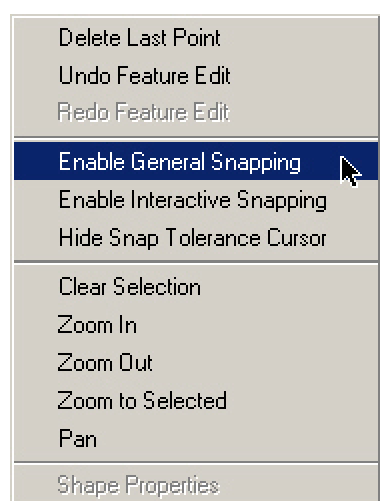
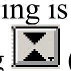


Figure 7-7. Stream attribute table after labeling river reaches.

Creating a Junction



For this example we will create the junction using the General Snapping method. Note that junction must have the endpoints of all three reach coincident. Use the **Zoom In** tool to zoom into the junction of interest. Now right-click in the window and select **Enable General Snapping**.

When general snapping is activated, the general snapping  (**Snap**

Tolerance) tool will appear on the tool bar. Activate the **Snap Tolerance** tool. Now set the general snap tolerance using the cursor. You do this by left-clicking-and-holding the mouse button. A circle will form as you drag the cursor (release when finished). The circle indicates the snapping tolerance for the endpoints.

Next activate the  **(Vertex)** tool. Click on one of the reach endpoints (holding the mouse button down) and drag it toward the junction. The circle that appears around the endpoint is the same snapping tolerance set previously. When you release the mouse button the endpoint will snap to whatever vertex is within the circle.

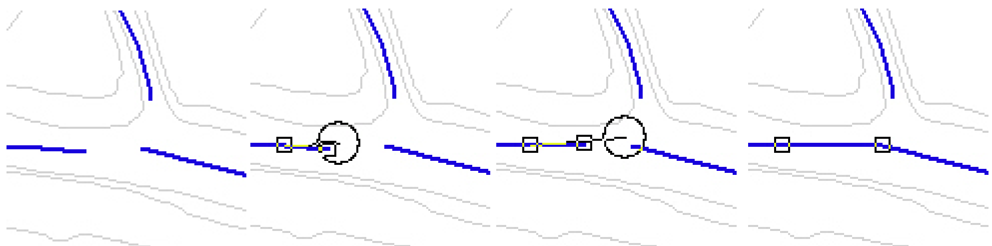


Figure 7-8. Progression for creating a junction using the General Snapping technique.

Do the same for the tributary. The Stream Centerline theme has now been created. Double-check that it was created in the downstream direction and that all reaches have been named. You will double-check the connectivity later in the Theme Attributing section.

Main Channel Banks

The Main Channel Banks theme is used to identify the main channel conveyance area from that of the overbank floodplain areas. This theme is not required and there are good tools within HEC-RAS for locating bank stations; however, laying out the bank station lines in the GIS will require you to read the terrain. This results in greater insight to water movement in the floodplain and in identifying non-conveyance areas.

Select the **preRAS ⇒ Banks** menu item. The Banks theme shapefile (blank) will be created, tagged, added to the view. It will be active and editable.

Establish the bank station location on either side of the channel for the Baxter River and Teal Creek using the Draw Line tool. Use the pan and zoom tools discussed earlier to navigate. Make sure that there is only one line for each bank station location. It may be necessary during this process to turn on the Terrain TIN and zoom way in to really see the channel definition. When finished digitizing the bank lines select **Theme ⇒ Stop Editing** to save the edits. The resultant bank lines for this example are illustrated in Figure 7-9.

Figure 7-9. Bank lines delineate the main channel from the overbank areas.

Flow Path Centerlines

The Flow Path Centerlines theme is used to determine downstream reach lengths between cross sections in the channel and overbanks areas. A flow path line should be created in the centerof mass of flow in the main channel and overbank areas for the water surface profile to be studied.

Select the **preRAS ⇒ Create Flowpaths** menu item. Because you have already created the Stream Centerline theme, a dialog box will appear asking you if the center flow path should be copied from the Stream Centerline theme. Press **Yes** to copy the centerline.

Create flow paths in the left and right overbank for each of the rivers using the **Draw Line** tool. Create the flow paths in the direction of flow (from upstream to downstream) and located to indicate the center of mass of flow for a specific event. When finished, select **Theme ⇒ Stop Editing** menu item. Your flow path lines should look similar to those in Figure 7-10.

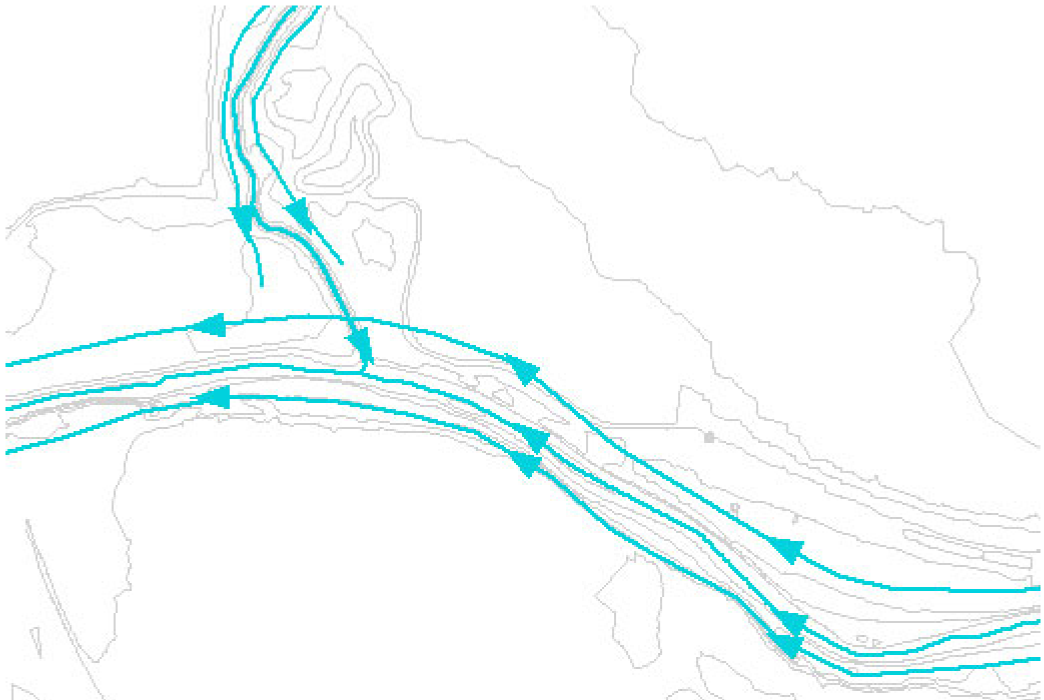


Figure 7-10. Illustration of flow path centerlines.

Now label each flow path with an identifier. Activate the 

(**Label Flowpaths**) tool. Use the cursor in the display window to select a flow path. Upon selection, the dialog shown in Figure 7-11 will appear. Select the correct label from the drop down list for the left overbank, channel, and right overbank flow paths.

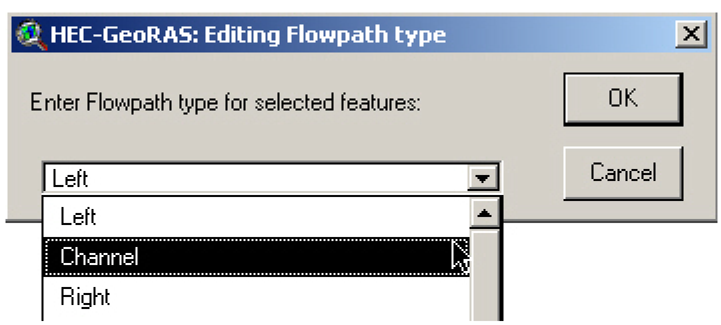


Figure 7-11. Each flow path must have an identifier of "Left"," Channel", or "Right".

Check that the flow path type has been identified for each flow path. Open the flow path attribute table and verify that the *LineType* field has data for each polyline. The attributes for the Baxter River example flow paths theme is shown in Figure 7-12. Note that there is a *Stream_ID* and *Reach_ID* field. This field was added when we copied the Stream Centerline theme for the "Channel" flow path. Therefore, there are only Stream and Reach names provided for the Channel flow path.

Attributes of Flowpaths.shp

Shape	Stream_id	Reach_id	Sr_id	Linetype
PolyLine	Baxter River	Upper	0	Channel
PolyLine	Baxter River	Lower	1	Channel
PolyLine	Teal Creek	Tributary	2	Channel
PolyLine			0	Right
PolyLine			0	Left
PolyLine			0	Left
PolyLine			0	Right

Figure 7-12. Flow path attribute table with the LineType field data properly entered.

Cross-Sectional Cut Lines

Cross-sectional cut lines are used to identify the location cross-sectional data is extracted from the Terrain TIN. The intersection of the cut lines with the other RAS Themes will determine bank station locations, downstream reach lengths, Manning's *n* values, levee positions, and ineffective flow areas.

Cut lines should always be located perpendicular to the direction of flow and oriented from the left bank to right bank. Cut lines must cover the entire extent of the floodplain to be modeled. Creating the Flow Path Centerlines theme previously will assist you in laying out the cut line perpendicular to flow.

Select the **preRAS ⇒ Create Flow Paths** menu item. Use the **Draw Line** tool to create cut lines. Use the mouse to draw the cut lines from the left overbank to the right overbank dog-legging the cut line perpendicular to the flow path lines. When finished, select the **Theme ⇒ Stop Editing** menu item. The cross-sectional cut lines for the Baxter River are shown in Figure 7-13.

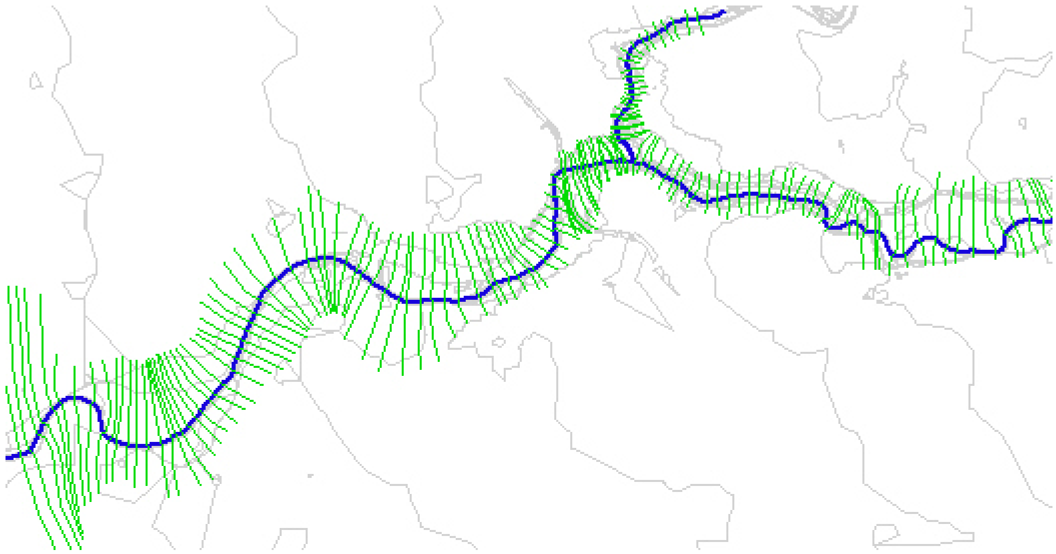
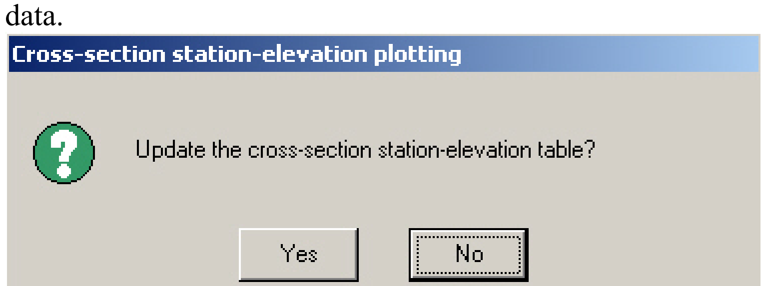


Figure 7-13. Cross-sectional cut lines span the entire floodplain.

Previewing Cross Sections

After cut lines are digitized, the cross sections that will be extracted from the Terrain TIN can be previewed. This is often useful to check that the cut line spans the entire floodplain and to identify the flow distribution through a cross section. To preview a cross section, follow the steps listed below.

1. Select the  (**XS Plot**) tool.
2. Select **Yes** in the dialog that appears to extract the cross-sectional data.

   Only update the table if the cut lines have been altered since the last time you previewed a cross section.
3. Use the  cursor to select the cross section of interest.
4. The cross section will be plotted in a chart window, as shown in Figure 7-14.

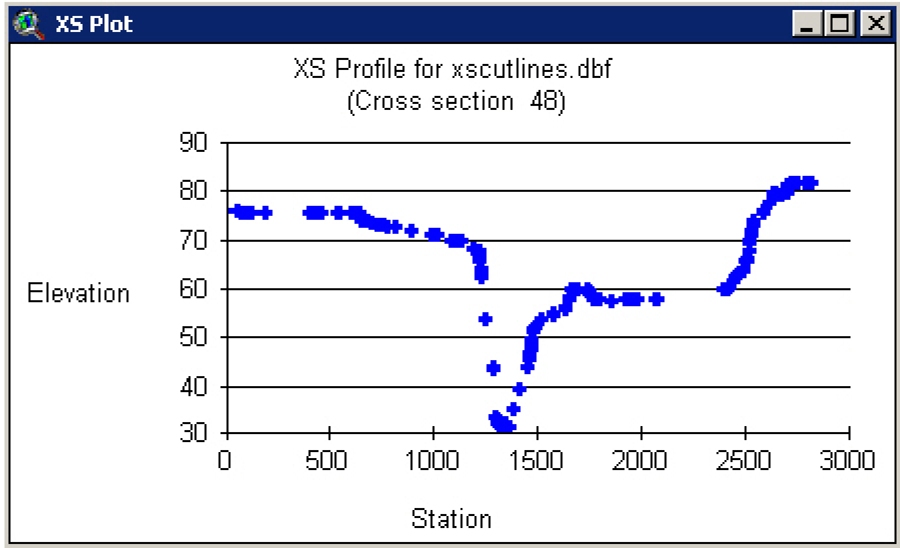
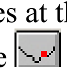


Figure 7-14. Cross section preview using the XS Plot tool.

Note that for this example, the cross section plot is labeled "Cross section 48". If the cross section has *Station* attributes, the stationing is used for the label.

Now lets check the location of our bank station lines at the cross section. With the *XS Plot* window active, select the  (**Point Identify**) tool. This will give you a bulls-eye cursor to identify a point; use it to click at the location of the bank stations on the cross section plot. Red graphic dots will be drawn to the view window, identifying the location along the cross section, as shown in Figure 7-15.

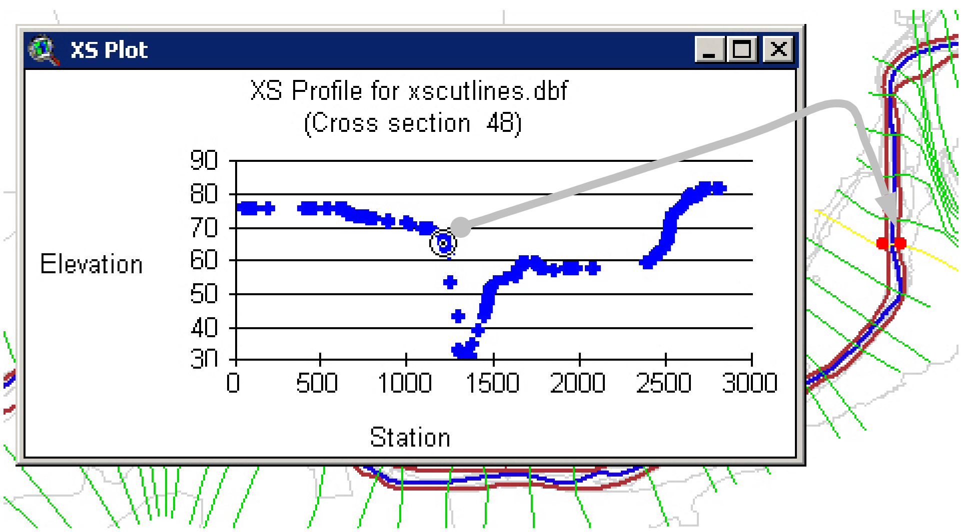


Figure 7-15. Use the Point ID tool to locate points in a cross section

Land Use

The Land Use theme is used to establish roughness coefficients for each cut line. The Land Use theme must be a polygon theme and have a field titled *N_value* in its attributes.

For this example, we have a simple land use theme for the area surrounding Tule Town. As depicted in Figure 7-16, there are many land use categories and even more polygons that need to have an *n* value assignment.

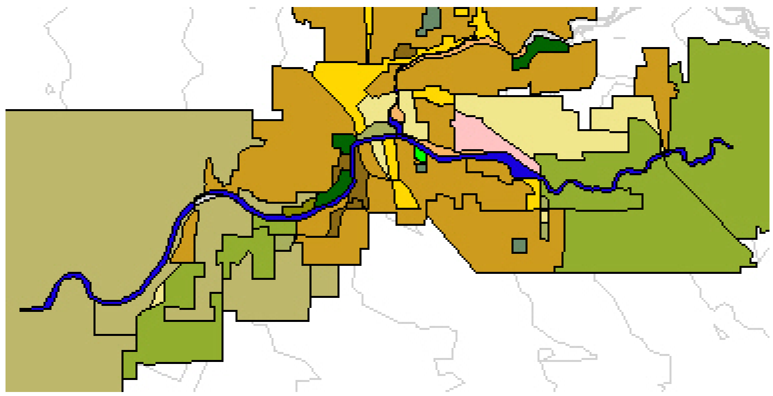


Figure 7-16. Land Use data for the vicinity of Tule Town.

The example land use data set does not have an *N_value* field, so we need to add it. Make the Land Use theme active. Select the **GeoRAS_Util ⇒ Create LU-Manning Table** menu item. In the dialog that is invoked, select the field that holds the description of the land use data.

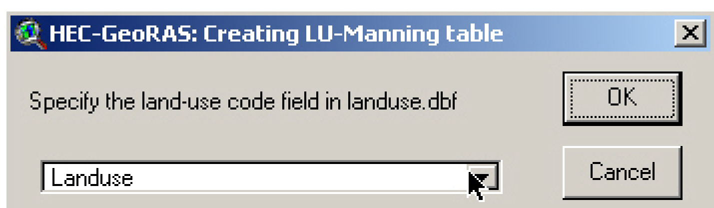


Figure 7-17. Select the land use description field.

A file browser will then appear allowing you to choose the name of the lookup file ("lumanning.dbf" is default) that will summarize the land use categories and allow you to enter *n* values. This table will be joined to the Land Use theme. Choose a filename and location and press **OK**.

From the *project* window, select the *tables* document. The name of the table ("lumanning.dbf") will appear as an available document. **Open** the table by double-clicking on it. The table will open and the field names will appear in italics. Note that the table is a summary of land use categories and has a blank field titled *N_value*. The *N_value* field has been joined to the Land Use theme.

Select the **Table** ⇒ **Start Editing** menu item to begin entering *n* values. (Note that the field names are no longer in italics, indicating that the table is in edit mode.) Use the (**Edit Cells**) tool to edit values in the table. When finished entering *n* values, select **Table** ⇒ **Stop Editing**.

lumanning.dbf

Landuse	N_value
Urban	0.060
HDResidential	0.080
Industrial	0.100
Orchards	0.055
OpenSpace	0.045
Crop/Pasture	0.050
Commercial	0.120
School	0.055
Floodplain	0.040
OpenWater	0.035
GolfCourse	0.000
WWTP	0.000
Park	0.000
Airport	0.000

Figure 7-18. Example "lumanning" table with land use description and estimated n values.

Select the view document ("BaxterRiver") used for creating the themes to access the GeoRAS menus. Open the Land Use theme attribute table. Note that the field *N_value* has been joined from the "lumanning" table.

Attributes of Landuse.shp

Shape	*Landuse*	*N_value*
Polygon	Urban	0.060
Polygon	HDResidential	0.080
Polygon	HDResidential	0.080
Polygon	Industrial	0.100

Figure 7-19. The N_value field will be joined to the Land Use theme.

Levee Alignment

The Levee Alignment theme is used to identify features that impede or direct the flow of water from moving out into the floodplain.

In our example, the rather well-to-do members of Bushwood Country Club have elected to construct a levee to protect their beloved homes. Despite the fact that this levee is not in our Terrain TIN, we can incorporate their proposed plans into our GeoRAS model development.

Select the **preRAS** ⇒ **Create Levee Alignment** menu item. Using the **Draw Line** tool, digitize the levee alignment. The levee alignment on Baxter River protecting Bushwood Estates is shown in Figure 7-20.

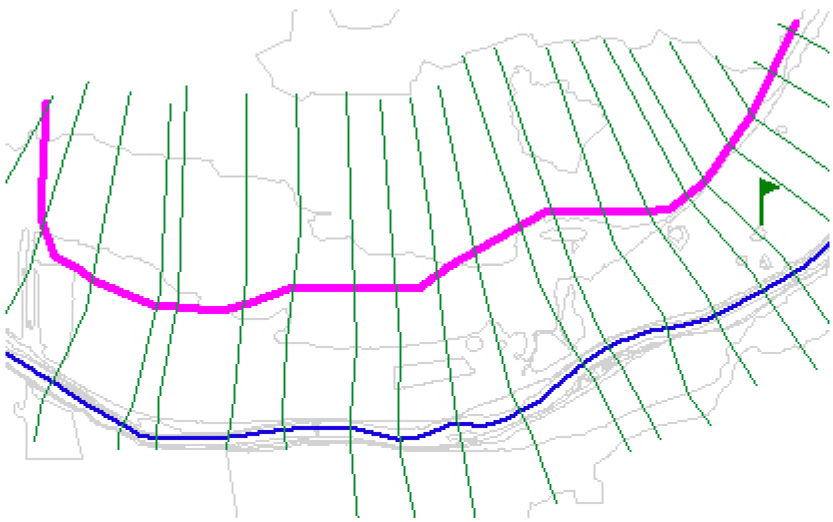


Figure 7-20. Levee alignment for Bushwood Estates.

Once the levee alignment has been digitized, enter the *Levee_ID* in the Levee Alignment attribute table. For this example, the levee is called "Bushwood".

Figure 7-21. Levee Alignment theme attribute table.

Next, the levee elevation profile data must be entered. Luckily for us, the contractor who is building the levee has the information we need and we can easily enter it visually using the  (**Levee Elevations**) tool. Once the Levee Elevations tool is active click, on a location to enter an elevation. The dialog shown in Figure 7-22 will be invoked showing you what the ground elevation is at that point and allowing you to specify a new elevation.

Figure 7-22. Enter the new levee elevation for the specified point.

The elevation will be written to a new table called "LeveeBushwood" (for our example). If you make a mistake and do not want a new elevation at the specified point, press the Cancel button. The "LeveeBushwood" table can also be edited using standard ArcView table editing tools. The levee profile results are shown in Figure 7-23 along with the locations of data entry.

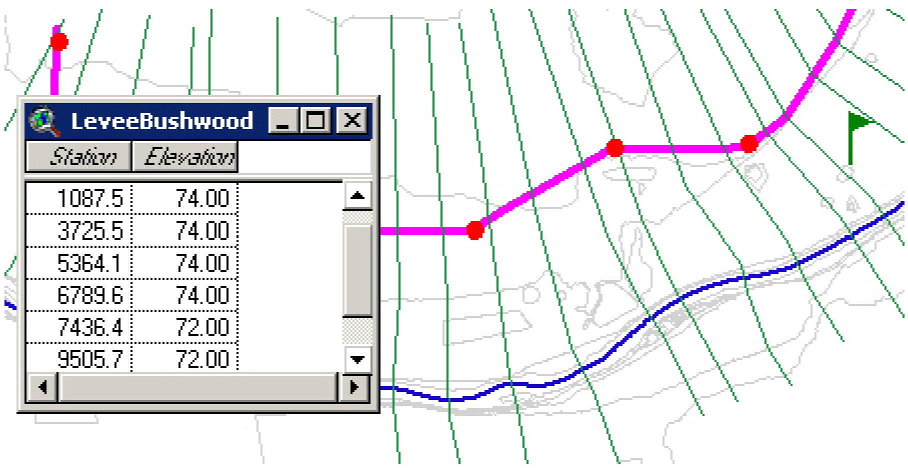


Figure 7-23. Levee profile data is stored in a separate table. Locations for data entry are depicted as dots.

You now have a levee alignment and profile data, but this must be converted to a continuous elevation profile. Select the **GeoRAS_Util ⇒ Levee Profile Completion** menu item. This will convert the 2D levee alignment to a 3D levee shapefile. The process uses the *Station* and *Elevation* data to interpolate elevations along the levee alignment and saves it as a new 3D levee profile. Now we can get the position and elevation at any point along the Levee Alignment (3D) theme.

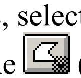
For our example, we used a "proposed" levee – a levee that was not incorporated in the terrain data. If the levee was represented in the terrain data, we would only need to digitize the alignment. When running the **Levee Profile Completion** process, elevation data would have been taken directly from the Terrain TIN.

Ineffective Flow Areas

Ineffective flow areas are used to define areas that are not actively conveying water.

There are many bridges across the Baxter River, so we lay out ineffective flow areas based on flow contracting as it approaches the bridge opening and expanding as it exits the bridge. An example set of ineffective flow areas are shown in Figure 7-24.

Figure 7-24. Ineffective flow areas at a bridge.

To create ineffective flow areas, select **preRAS ⇒ Create Ineff. Flow Areas** menu item. Use the  (**Draw Polygon**) tool to digitize the bounds of the ineffective flow area polygon. Once the ineffective flow area has been digitized, open the Ineffective Flow Area theme table and enter an *IA_ID*. (If you have many ineffective areas, you can leave the naming up to GeoRAS. We will look at this during the *Attributing RAS Themes* section of this example.)

Storage Areas

Storage areas are used in unsteady-flow modeling to represent floodplain storage. Storage areas must be connected to the main conveyance channel in HEC-RAS.

For our example, there are two areas of low-lying land that will store water during flood events. In other words, water will flow into the areas during the rise of the hydrograph and may flow back into the river during hydrograph recession.

To create the storage area, select the **preRAS ⇒ Create Storage Areas** menu item. Use the  (**Draw Polygon**) tool to digitize the bounds of the storage area polygon. Once the storage area has been digitized, open the Storage Area attribute table and enter the *SA_ID*. As shown in Figure 7-25 and Figure 7-26, our storage areas are called "Northside" and "Southside".

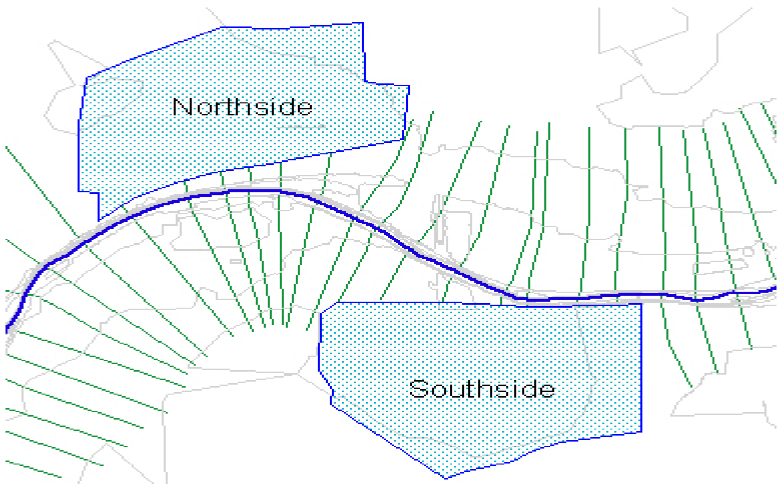
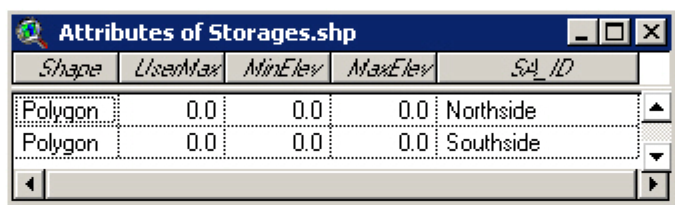


Figure 7-25. Storage areas along Baxter River.



Attributes of Storages.shp

Shape	UserMax	MinElev	MaxElev	SA_ID
Polygon	0.0	0.0	0.0	Northside
Polygon	0.0	0.0	0.0	Southside

Figure 7-26. Storage Area theme attribute table.

Note that the Storage Area attribute table has several fields with no data ("0.0"). The *MinElev* and *MaxElev* fields will be automatically filled in later during the storage area elevation-volume calculation. If however, you wanted to override the calculated *MaxElev* you could specify the *UserMax* as the maximum elevation, to extend the elevation-volume rating curve. For this example we will not specify an alternative maximum elevation.

Attributing RAS Themes

Thus far you have created (digitized) the GIS RAS Themes needed to extract geometric data for HEC-RAS. The theme attributing process is where the GIS performs calculations using the RAS Themes and appends the results to corresponding tables. The two main themes which have data appended to their tables are the Stream Centerline theme and the Cross-Sectional Cut Line theme.

Before attributing the themes, make sure that you have the correct themes specified. You do this through the **preRAS ⇒ Theme Setup** menu item. Using the drop-down lists in the pre-processing dialog window, select the theme corresponding to the Terrain TIN and all of the "Input Data" fields. At this time, also enter the name for the RAS GIS Import File. The theme setup for this example is shown in Figure 7-27. We will create this file later.

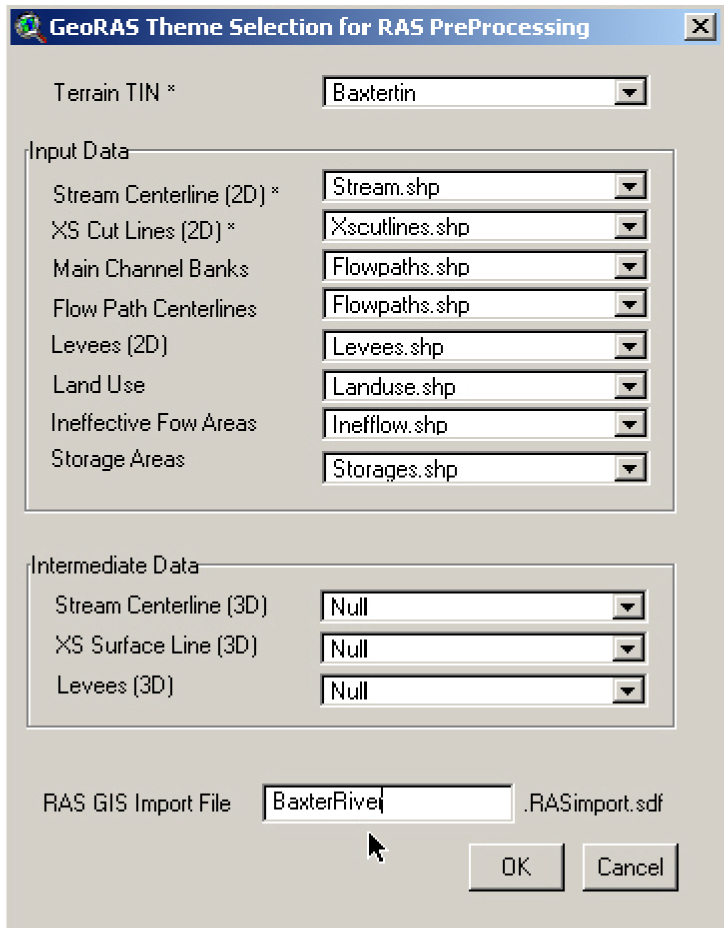


Figure 7-27. Theme Setup for the Baxter River example.

Stream Centerline Theme

Select the **preRAS ⇒ Centerline Completion** menu item. This will run the **Centerline Topology** and **Lengths/Stations** menu items. The centerline topology establishes the river connectivity and adds the *from_Node* and *to_Node* fields to the Stream Centerline theme. Check these fields to make sure they make sense. What "makes sense"? Well, make sure that at each junction the reach endpoints all share a common node number (in this example, you have 2 *to_Node*s that have the same *from_Node* at the junction). The completed attribute table is shown in Figure 7-28.

Attributes of Stream.shp

Shape	Stream_id	Reach_id	from_Node	to_Node	to_ST	from_ST	ArcLength
PolyLine	Baxter River	Upper	1	2	89378.410	48157.068	41221.342
PolyLine	Baxter River	Lower	2	3	48157.068	0.000	48157.068
PolyLine	Teal Creek	Tributary	4	2	12551.497	0.000	12551.497

Figure 7-28. Completed Stream Centerline theme attribute table.

The **Lengths/Stations** item calculates the starting and ending station of each reach and calculates the corresponding length. (Note that the to/from Nodes work in the direction of flow, while the stationing to/from ST works from downstream to upstream.)

After the Stream Centerline theme has been attributed, convert the 2D shapefile to a 3D shapefile. Select the **preRAS** ⇒ **Centerline Elevations** menu item. This will extract elevations along the centerline from the Terrain TIN. This new 3D shapefile is what will be written to the RAS GIS Import File, later in this example.

Cross-Sectional Cut Lines Theme

Cross-sectional attributes are added to the Cross-Sectional Cut Lines theme using the menu items located under the XS Attributing menu item. Selecting the XS Attributing menu item will run in sequence the Stream/Reach Names, Station, Bank Stations, and Reach Lengths menu items.

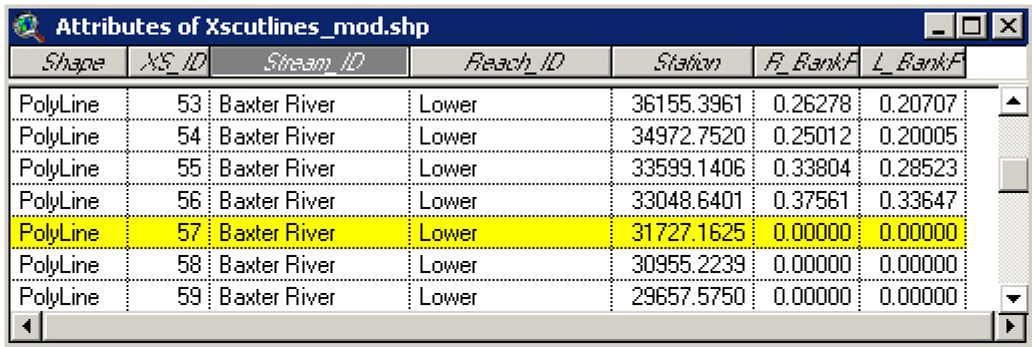
Select each individual menu item in sequence noting whether the process runs to a successful completion. If successful, the cut line attribute table will look something like that shown in Figure 7-29. **Stream/Reach Names** adds the *XS_ID*, *Stream_ID*, and *Reach_ID* fields; **Station** menu item adds the *Station* field; **Bank Stations** adds the *R_BankP* and *L_BankP* fields; and **Reach Lengths** adds the *R_ReachL*, *M_ReachL*, and *L_ReachL* fields.

Attributes of Xscutlines_mod.shp

Shape	XS_ID	Stream_ID	Reach_ID	Station	R_BankP	L_BankP	R_ReachL	M_ReachL	L_ReachL
PolyLine	0	Baxter River	Upper	84815.6874	0.63137	0.54172	627.648	815.245	343.447
PolyLine	1	Baxter River	Upper	81919.7665	0.34924	0.21430	246.866	201.868	110.898
PolyLine	2	Baxter River	Upper	79082.3690	0.61825	0.51690	444.333	424.179	254.462
PolyLine	3	Baxter River	Upper	77909.1608	0.57292	0.46353	232.757	229.201	224.387

Figure 7-29. Cross-Sectional Cut Line attribute table.

If, however, the cut lines and another RAS Theme are not properly digitized and attributed, processing will stop. For this example, the cut lines did not extend across both bank lines. Therefore, when we ran the Bank Stations menu item, GeoRAS gave an error message: "There are not exactly 2 bank lines intersecting a single cross section! Bank percentage calculations FAILED." This is a good error message, but now we need to know which cross section failed. Open the cut lines table and the answer pops out. The cross section that failed is the "first" cross section that has "0.00000" where some positive fraction should be. Take a look at the cut line table shown in Figure 7-30. The bad cross section has an *XS_ID* of "57".



Attributes of Xscutlines_mod.shp

Shape	XS_ID	Stream_ID	Reach_ID	Station	R_BankF	L_BankF
PolyLine	53	Baxter River	Lower	36155.3961	0.26278	0.20707
PolyLine	54	Baxter River	Lower	34972.7520	0.25012	0.20005
PolyLine	55	Baxter River	Lower	33599.1406	0.33804	0.28523
PolyLine	56	Baxter River	Lower	33048.6401	0.37561	0.33647
PolyLine	57	Baxter River	Lower	31727.1625	0.00000	0.00000
PolyLine	58	Baxter River	Lower	30955.2239	0.00000	0.00000
PolyLine	59	Baxter River	Lower	29657.5750	0.00000	0.00000

Figure 7-30. Debugging GeoRAS problems in the Cross-Sectional Cut Line table.

Once you have the attribute table open. You can scroll through and find the corrupt cross section. Use the **Select** tool to highlight the cross-sectional cut line, then go back to your view and zoom into the current selection. Once zoomed in, you should be able to figure out what caused the problem!

Extract Cross-Sectional Elevations

To finish the with the cut line theme, extract the terrain elevations. Select the **preRAS ⇒ XS Elevations** menu item. The 2D cut lines theme will be converted to a 3D shapefile by extracting elevations from the Terrain TIN. An elevation is extracted each time the cut line crosses and triangle edge in the TIN. The attribute table for the 3D shapefile will be identical to the 2D shapefile.

Manning's n Values

Manning's *n* values for each cross-sectional cut line will be extracted from the Land Use theme, if the Land Use theme has an *N_value* field. Extract the estimated *n* values by selecting the **preRAS ⇒ Manning's *n* values** menu item. This will create a new table of *n* value data for each cross-sectional cut line. The table is called "Manning" and is shown in Figure 7-31.

Manning

Xs_id	Fraction	N_value	Reach_ID	Stream_ID
0	0.00000	0.055	Upper	Baxter River
0	0.52623	0.035	Upper	Baxter River
0	0.64920	0.055	Upper	Baxter River
1	0.00000	0.055	Upper	Baxter River
1	0.19711	0.035	Upper	Baxter River
1	0.36261	0.055	Upper	Baxter River
2	0.00000	0.055	Upper	Baxter River
2	0.50264	0.035	Upper	Baxter River
2	0.63387	0.055	Upper	Baxter River

Figure 7-31. Example Manning table cross section n values.

Levee Positions

Levee positions for each cross-sectional cut line will be extracted for each levee in the 3D Levee theme. (Note that HEC-RAS 3.1 supports only one levee per bank.)

Select the **preRAS ⇒ Levee Positions** menu item. The intersection of the Levee (3D) theme and the Cross-Sectional Cut Lines theme will locate levee positions for each cut line. Levee elevations will be taken from the Levee (3D) theme. Levee position data will be written to a table called "Levee Positions", as shown in Figure 7-32.

Levee Positions

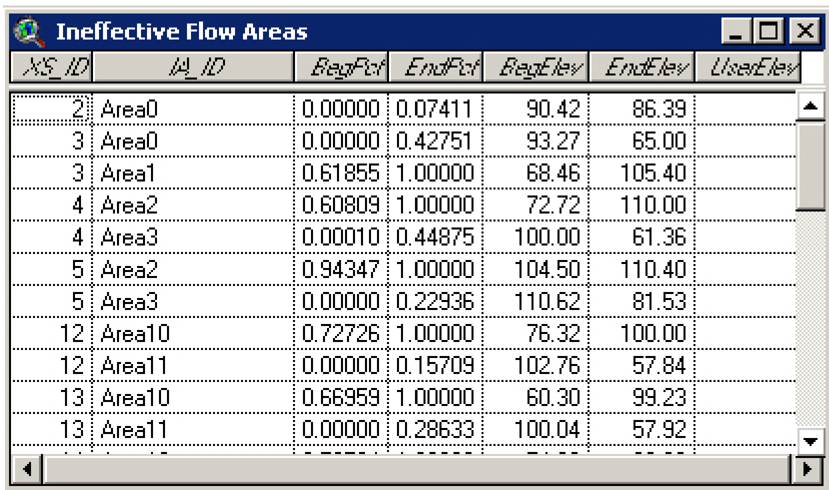
XS_ID	Levee_ID	Position	GrndElev	Elev	Fr
50	Bushwood	0.77908	71.72	74.00	Lower
51	Bushwood	0.59790	67.64	74.00	Lower
52	Bushwood	0.52305	73.84	74.00	Lower
53	Bushwood	0.58775	73.84	74.00	Lower
54	Bushwood	0.60676	73.84	74.00	Lower
55	Bushwood	0.61174	64.35	74.00	Lower
56	Bushwood	0.62653	64.98	74.00	Lower
57	Bushwood	0.40547	61.08	72.34	Lower
58	Bushwood	0.39115	55.84	72.00	Lower
59	Bushwood	0.47155	55.22	72.00	Lower
60	Bushwood	0.61776	62.82	72.52	Lower

Figure 7-32. Levee position data for selected cross sections.

Ineffective Flow Areas

Ineffective flow areas for each cross section will be determined from the intersection of the Ineffective Flow Areas Theme and the Cross-Sectional Cut Lines theme.

Select the **preRAS ⇒ Ineffective Flow Areas** menu item. If the ineffective flow area identifier *IA_ID* has not been uniquely specified, GeoRAS will automatically generate it for you (as is done in this example). The intersection of each ineffective flow area with a cut line and the corresponding terrain elevation will be calculated and reported to a table called "Ineffective Flow Areas". The fields *BegPct* and *EndPct* indicate the intersection points at each *XS_ID* and *BegElev* and *EndElev* report the associated terrain elevations. The higher of the two elevations will be used in HEC-RAS for the trigger elevation. If you wish , you can override the trigger elevation by editing the table under the *UserElev* field. An example ineffective flow areas table is shown in Figure 7-33.


Ineffective Flow Areas

XS_ID	IA_ID	BegPct	EndPct	BegElev	EndElev	UserElev
2	Area0	0.00000	0.07411	90.42	86.39	
3	Area0	0.00000	0.42751	93.27	65.00	
3	Area1	0.61855	1.00000	68.46	105.40	
4	Area2	0.60809	1.00000	72.72	110.00	
4	Area3	0.00010	0.44875	100.00	61.36	
5	Area2	0.94347	1.00000	104.50	110.40	
5	Area3	0.00000	0.22936	110.62	81.53	
12	Area10	0.72726	1.00000	76.32	100.00	
12	Area11	0.00000	0.15709	102.76	57.84	
13	Area10	0.66959	1.00000	60.30	99.23	
13	Area11	0.00000	0.28633	100.04	57.92	

Figure 7-33. Ineffective flow areas attribute table.

Storage Area Completion

If you are performing a steady-flow analysis of your river system, you won't have any storage areas. For this example, we will assume you will be performing an unsteady-flow analysis.

Select the **preRAS ⇒ Storage Areas Completion** menu item. In this example we have already named the storage areas using the *SA_ID* field; however, GeoRAS will automatically give them a unique ID, if necessary.

GeoRAS will then ask you if you want to extract the terrain data from the Terrain TIN within each storage area (Figure 7-34). This would allow you to visualize flow exchange in the storage area with the river during unsteady flow analysis in HEC-RAS, but we will skip this step, as it is time-consuming to gather the terrain data (and the current version of HEC-RAS does perform the flow visualization in storage areas).

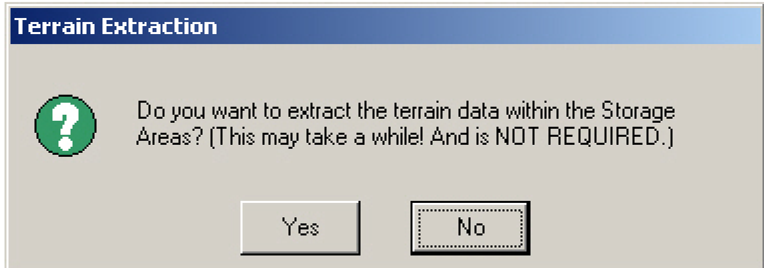
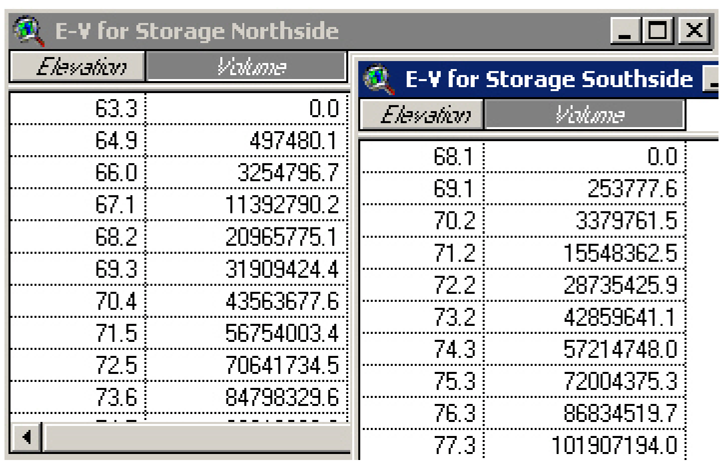


Figure 7-34. Select No to skip the terrain data extraction process.

The wait cursor will then appear and the Elevation-Volume relationship for each storage area will be calculated. The data will be written to tables using "E-V for Storage" as a prefix. In this example, the tables are "E-V for Storage Northside" and "E-V for Storage Southside". Elevations will be calculated for ten elevation intervals from the *MinElev* to the *MaxElev* as specified in the Storage Area attribute table. Example elevation-volume tables are shown in Figure 7-35.



E-V for Storage Northside

Elevation	Volume
63.3	0.0
64.9	497480.1
66.0	3254796.7
67.1	11392790.2
68.2	20965775.1
69.3	31909424.4
70.4	43563677.6
71.5	56754003.4
72.5	70641734.5
73.6	84798329.6

E-V for Storage Southside

Elevation	Volume
68.1	0.0
69.1	253777.6
70.2	3379761.5
71.2	15548362.5
72.2	28735425.9
73.2	42859641.1
74.3	57214748.0
75.3	72004375.3
76.3	86834519.7
77.3	101907194.0

Figure 7-35. Elevation-Volume data for Northside and Southside storage areas.

After the elevation-volume table has been created for each storage area, the 2D Storage Area shapefile will be converted to a 3D shapefile, using the Terrain TIN elevations for the elevations along the edge of each storage area. The 3D shapefile will be sent the RAS GIS Import File to show the location of storage areas to be modeled.

Generating the RAS GIS Import File

Once you have created the 3D Stream Centerline theme and 3D XS Cut Lines theme, you are ready to write the RAS GIS Import File. You specified the file name before ("BaxterRiver") in the **preRAS ⇒ Theme Setup**, but is always a good idea to check the filename again before you create the file.

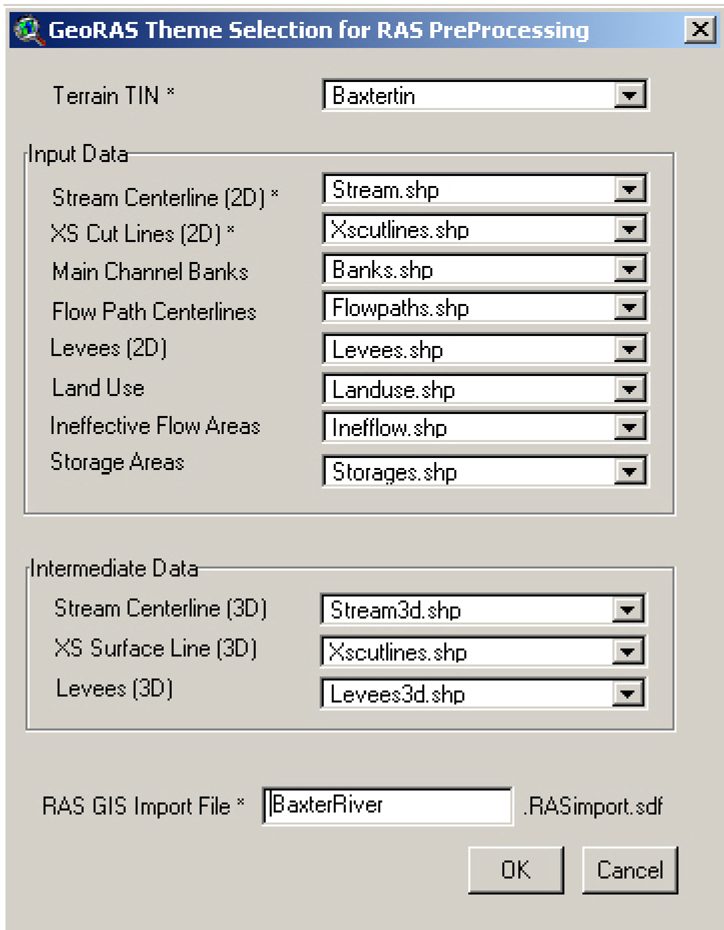


Figure 7-36. Use the preRAS Theme Setup to identify the correct shapefiles and RAS GIS Import File name.

You can use the Theme Setup dialog (shown in Figure 7-36) to double check that the correct shapefiles were used for extracting data (Input Data) and that the correct 3D shapefiles will be used to write the data to the RAS GIS Import File (Intermediate Data). (Note that required data is indicated by a asterisk (*); intermediate data is constructed from the 2D RAS Themes; and the file extension *.RASimport.sdf* will be added to the RAS GIS Import File name.)

Select **preRAS ⇒ Header Export**, **preRAS ⇒ Centerline Export**, **preRAS ⇒ XS Export** one by one to write the RAS GIS Import File.

If the Terrain TIN does not contain a projection file, you will be informed and then asked to specify the units of the Terrain TIN. The series of dialogs are shown below.

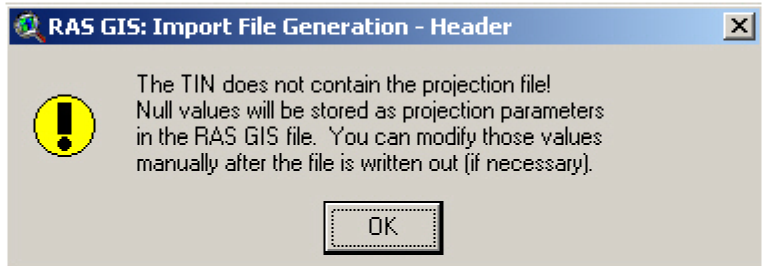


Figure 7-37. Dialog invoked if the Terrain TIN does not have a projection file.

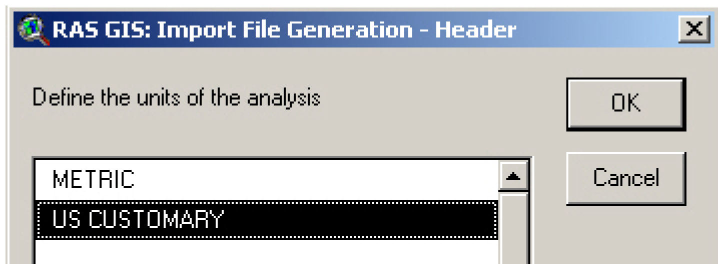


Figure 7-38. You must specify the units of the Terrain TIN if no projection file exists.

You will be informed after the successful completion of writing the header. Proceed to write the stream centerline, cross section, and storage area sections of the file. The status bar at the bottom of the ArcView GIS window will give you updates as the data is written to the data exchange file. You will be prompted if each part is successful or if it fails.

After generating each section of the RAS GIS Import File, you should open the file and check to see that all the data was written out. Check to make sure the number of river reaches is correct and the number of cross sections is right. Checking an ASCII text file for mistakes is not easy, but is a skill you will gain through experience.

HEC-RAS Hydraulic Analysis

HEC-RAS allows you to perform one-dimensional steady flow and unsteady flow analysis of river systems. The general steps in using HEC-RAS 3.1 in concert with GeoRAS, are discussed in the following section. A complete discussion on using the HEC-RAS 3.1 software, modeling guidelines, and technical information can be found in the HEC-RAS User's Manual, Applications Manual, and Hydraulic Technical Reference Manual.

Start a new project in HEC-RAS

Start a new project in HEC-RAS and save it to the directory you want the HEC-RAS file to be stored in.

Import the RAS GIS Import File

Open the Geometric Data Editor and select **File ⇒ Import Geometry Data ⇒ GIS Format**. Browse to the RAS GIS Import File *BaxterRiver.RASimport.sdf* and select it. The data will be read in and the Import Options window will allow you to select the data to import. Go through each of the import options, selecting those that are appropriate. The default option is to import all the data in the RAS GIS Import File. Once the data has imported, the Geometric Data Editor schematic will show a georeferenced schematic of the river system, as shown in Figure 7-39. You will see the stream alignment, cross section locations, bank stations, levees, ineffective flow area locations, storage areas, and feature labels.

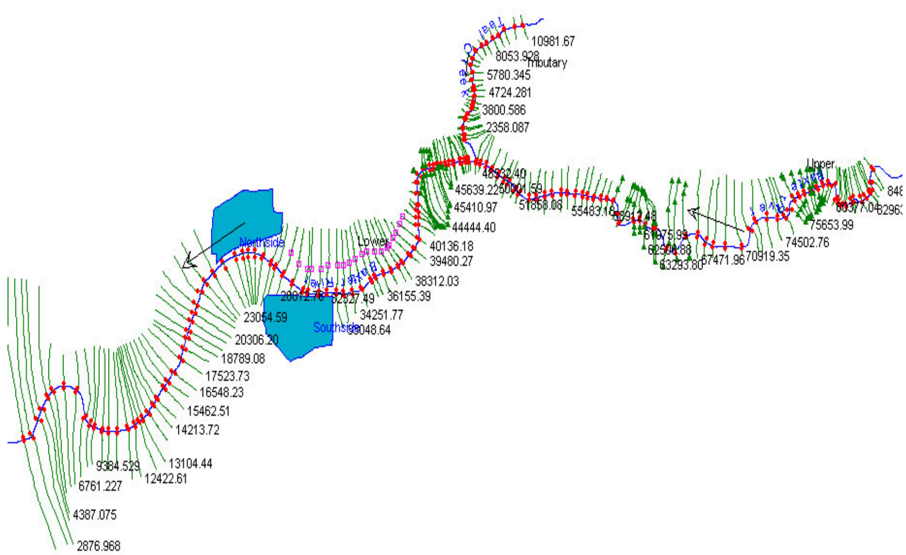


Figure 7-39. Georeferenced HEC-RAS schematic generated from imported GIS data.

After importing the geometric data, the first thing you will need to do is perform a quality control check on the data. Make sure there is no obviously erroneous data or missing data. Next, look at your data more closely by going through each cross section plot. Check that Manning's *n* values are reasonable, bank stations are placed correctly, levees and ineffective flow areas are placed correctly spatially and have the correct vertical component, check that no cross section has more than 500 points using the multiple cross section points filter, etc.

One of the best tools for visualizing and editing data is the Graphical Cross Section Editor.

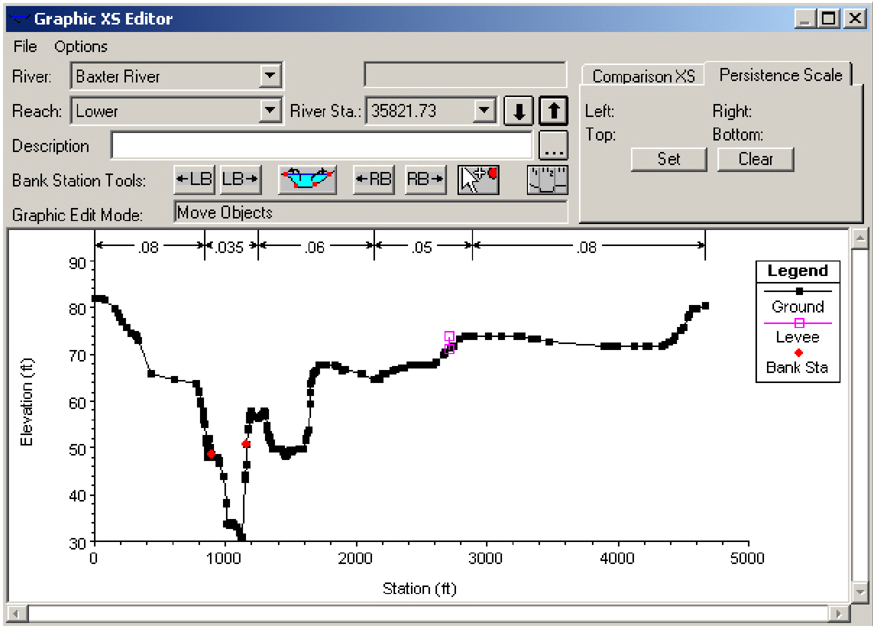


Figure 7-40. Graphical Cross Section Editor in HEC-RAS.

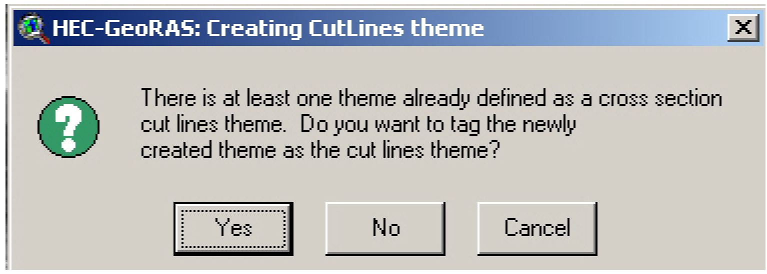
There are many other tools available in HEC-RAS Geometric Data Editor accessible through the Tables menu and Tools menu for completing and editing data.

Complete the hydraulic structure data

Bridges, culverts, and weirs must be entered by hand using the HEC-RAS editors. For each structure, you must input the geometric data and hydraulic coefficients. Further, the hydraulic structure data will affect the affective flow areas through bounding cross sections.

In this example, we have two storage areas that we must connect with the main channel. Lateral weirs are used to connect the storage areas to the main channel. The storage areas were constructed behind roads, so we can use the top-of-road profile for the lateral weir profiles. You can use GeoRAS to extract this data using the  (**XS Plot**) tool.

Consider the weir profile to be an additional cross section. Select the **preRAS ⇒ Create XS Cut Lines** menu item. A dialog will come up asking if you want to "tag" the new theme as being the XS Cut Lines theme. Chose **Yes** so that GeoRAS knows which theme the XS Plot tool should work on. (Note that you will have to use the **preRAS ⇒ Theme Setup** later to select the correct XS Cut Lines theme to use the XS Attributing functions.) Make sure to override the default theme name with a good name (like "Weirs").



Now digitize the weir cut line using the **Draw Line** tool. Make sure to digitize the weir line from upstream to downstream, as this is the direction HEC-RAS will use it. Once you have drawn your weir lines, stop editing the theme. An example weir for the "Northside" storage area is shown in Figure 7-41.

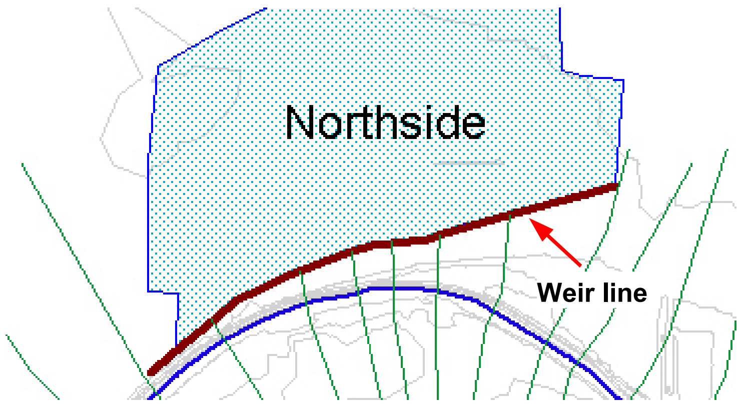


Figure 7-41. Storage area with weir line.

Now that the weir lines are drawn, use the **XS Plot** tool. When you select the **XS Plot** tool a file named "xsplot.dbf" is written to the directory where your project is saved. The station-elevation data can be copied from the *xsplot.dbf* file (using a spreadsheet) to the Weir/Embankment editor in HEC-RAS.

Complete the flow data and boundary conditions

For an unsteady flow analysis you will need to enter all inflow hydrographs, boundary conditions, and initial conditions through the Unsteady Flow Editor. We have entered an inflow hydrograph for the Baxter River and Teal Creek and a normal depth downstream boundary condition,for the Baxter River. The initial conditions were set to the "baseflow" conditions for each river reach. The storage area elevations were set to the minimum elevations based on the elevation-volume curve.

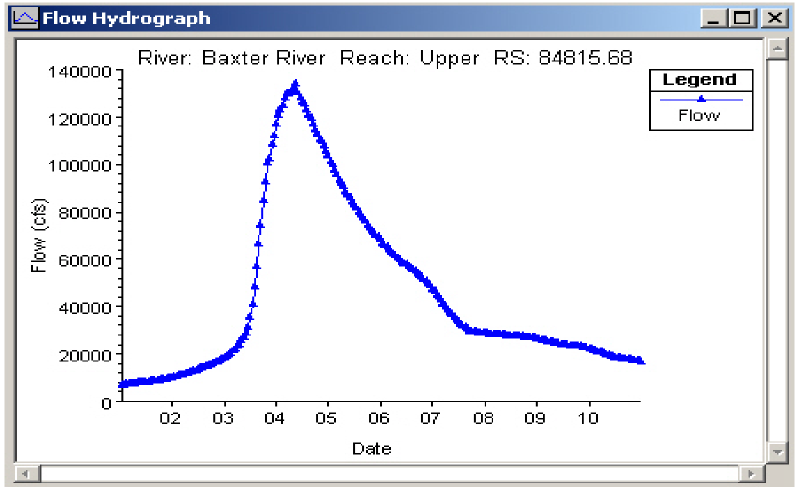


Figure 7-42. Inflow hydrograph for the Baxter River.

Run HEC-RAS

Next, you will need to go to the simulation window and enter the simulation time parameters and computation intervals. This is also where you will turn on the velocity distribution information, if you want to have velocity data available for export to the GIS. Select **Options ⇒ Flow Distribution Locations** to set the distribution of flow for each cross section.

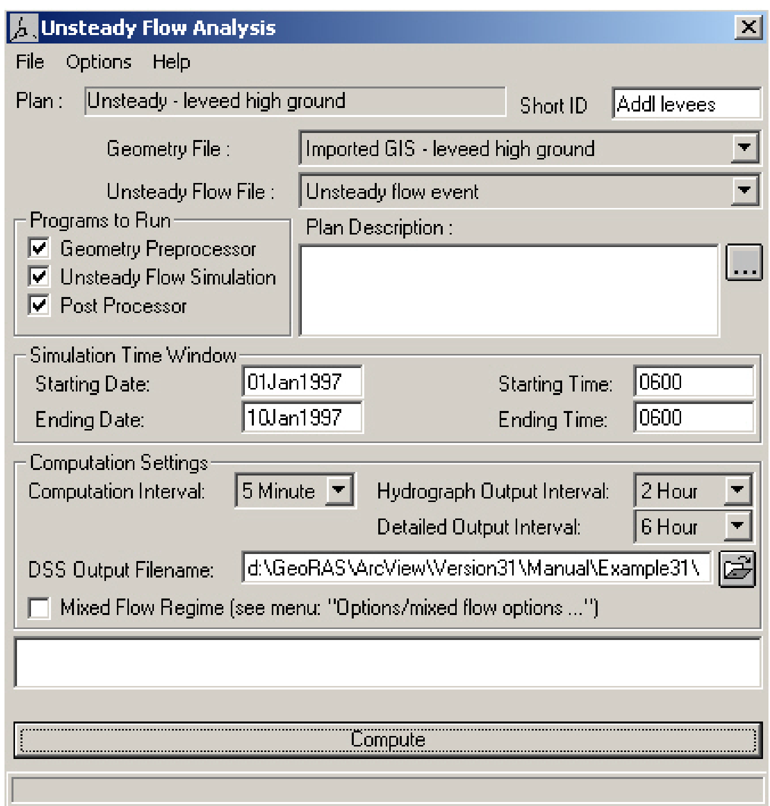


Figure 7-43. Unsteady Flow Analysis simulation window for HEC-RAS.

Next, run HEC-RAS by hitting the **Compute** button. During the run, a computation window will appear giving you the status of your run.

Review results and refine model

After simulating the hydraulic analysis, you will need to look at the detailed output HEC-RAS provides to see how to improve the hydraulic model. This may require going back to the GIS to get additional geometric data or just modifying what is in HEC-RAS. You will need to carefully look at the calculations performed at each hydraulic structure and identify how you can improve the calculations. Modify the boundary conditions, initial conditions, and the computation interval to make the model stable.

After going over all the data, simulate again. Now go back and review your results again and refine you model. Simulate, review, refine, repeat!

Bounding Polygon

Make sure to always check the “bounding polygon”, to make sure HEC-RAS is modeling the floodplain as you intended. If some of your GIS data not georeferenced, you will have problems getting the data back to the GIS.

To turn on the bounding polygon information, select the **Tools ⇒ Plot GIS Reach Bounds** menu item in the Geometric Data editor. Then select the river reaches of interest. The bounding polygon for the Baxter River model is shown in Figure 7-44.

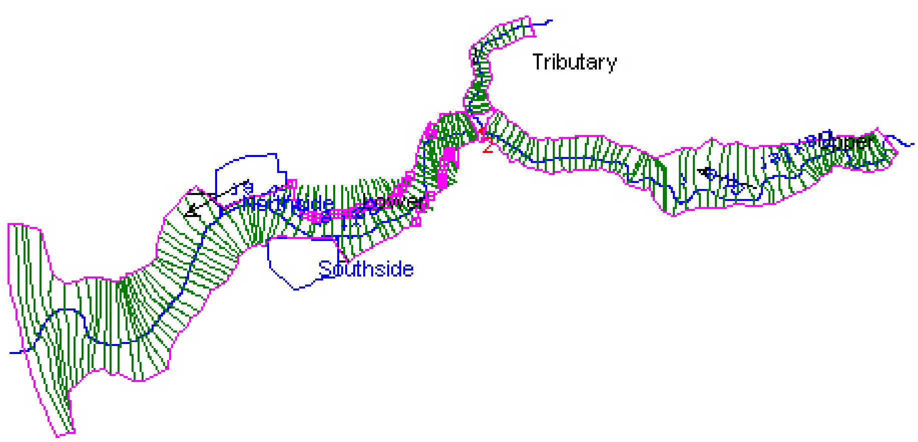


Figure 7-44. Bounding polygon for the Baxter River example.

The bounding polygon will reveal the absolute boundaries of the floodplain to be mapped in GeoRAS. Make sure that the cross sections are wide enough and spaced close enough together to capture the entire extent of the floodplain.

You can also quickly identify which bridges and levees were not over-topped during simulation, using the bounding polygon information in HEC-RAS.

Export results

Once satisfied with model results, you are ready to export the water surface profile(s) for processing in the GIS. From the main HEC-RAS window, select the **File ⇒ Export GIS Data** menu item. This will invoke the GIS Export window shown in Figure 7-45.

Enter the file name to for the GIS data and where to store the file. Select the water surface profile to write and any other additional data and press the **Export Data** button.

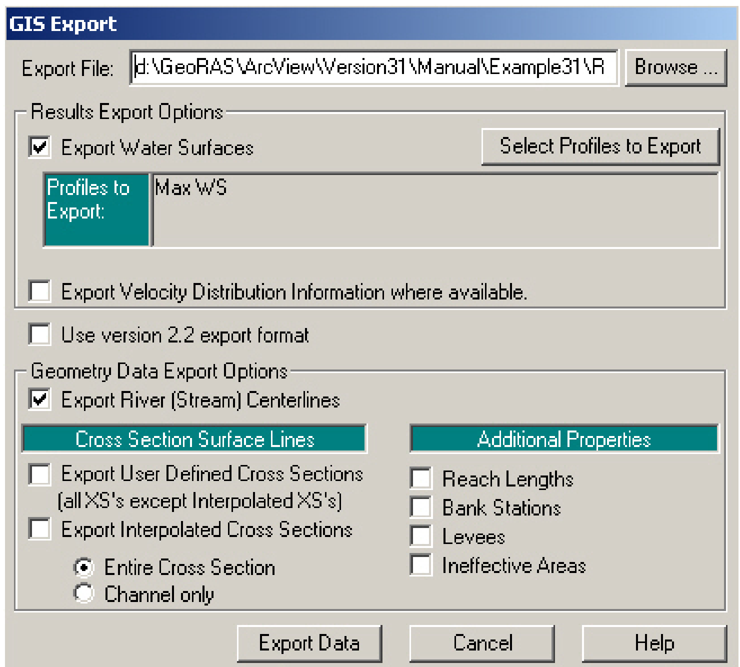


Figure 7-45. HEC-RAS GIS Export window.

Importing the RAS GIS Export File

Once the RAS GIS Export File has been created, read the data into the GIS and processes it to create a flood inundation map. Select the **postRAS ⇒ Theme Setup** menu item. This will invoke the post-processing dialog shown in Figure 7-46 (with empty fields). Select the RAS GIS Export File *(*.RASexport.sdf*), Terrain TIN, enter the Output Directory and Rasterization Cell Size, and press **OK**. This will create a new View (titled with the Output Directory name "MaxWsp") and create a new directory that will hold all the post-processing results from GeoRAS.

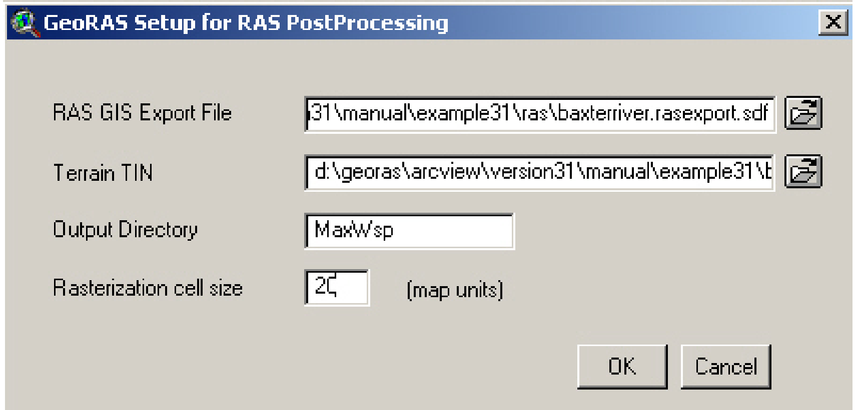


Figure 7-46. Post-processing theme setup dialog.

Next, select the **postRAS ⇒ RAS GIS Export File** menu item. This will read the results from the export file and create initial data sets. Shapefiles will automatically be created for the stream network, cross sections, and bounding polygon data. Other shapefiles may be created depending on the output options you selected when exporting the data from HEC-RAS. The Terrain TIN will be added to the *MaxWsp* view, as well.

Generating GIS Data from RAS Results

Now that the data has been read from the RAS GIS Export File and base data has been created, you are ready to create water surface and velocity data sets. All of the post-processing from this point forward will be done using the initial data sets created during the *Read RAS GIS Export File* step.

Water Surface TIN

Select the **postRAS ⇒ WS TIN Generation** menu item. The dialog shown in Figure 7-47 will be invoked allowing you to select the water surface profile to create the water surface TIN. In this case, we only have one profile to select (MaxWS). Click once on the profile and press the OK button to create the water surface TIN.

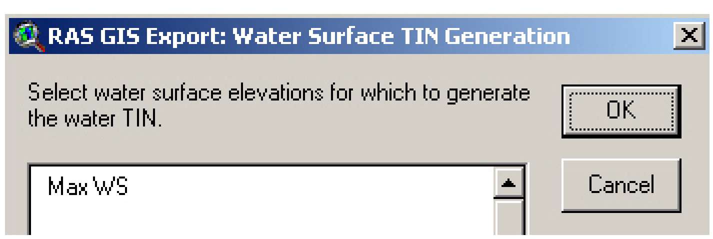


Figure 7-47. Select the water surface profile to map.

The water surface TIN will be created from the cross-sectional cut lines theme (“Maxwsp_xs”) and bounding polygon theme (“BP MaxWS”). The water surface TIN created will have the water surface profile name prefixed by “WS” (“WS MaxWS”) and will be added to the *MaxWsp* view. The actual TIN filename will be “wstinwsp000” and may be identified through the **Theme ⇒ Properties** dialog.

Floodplain Delineation

Select the **postRAS ⇒ Floodplain Delineation** menu item. This will delineate the floodplain for the “WS MaxWS” TIN. (If there were many water surface TINs, a dialog would have prompted you to choose those you wished to process.)

The floodplain delineation process will first create a depth grid using the Rasterization Cell Size to rasterize the water surface TIN and Terrain TIN and find the elevation difference. This depth grid will be called “GD MaxWS” in the view and saved as “gdwsp000” on the hard drive. (If you do not have the Spatial Analyst extension loaded, an additional point shapefile will be used to perform the grid calculations.) The associated floodplain will then be delineated based on the grid. This theme will be added to the view and called “FP MaxWS” with a filename of “fpwsp000.shp”.

Turn on the floodplain shapefile and take a look at the results. For this example, the floodplain shown in *Figure 7-48* is zoomed in to only a portion of our model.

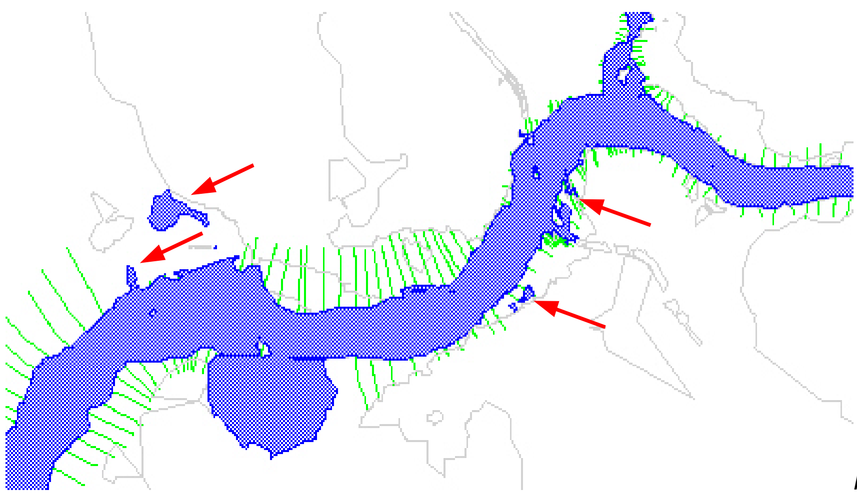


Figure 7-48. Initial floodplain delineation overlaying contours and cut lines.

Note that our delineation resulted in some “interesting” features, as indicated by the arrows in *Figure 7-48*. We have disconnected areas of flow, along with some other disconcerting inundation areas. Consider each piece of our floodplain and determine whether it makes hydraulic sense.

The areas to the North of the river are wet because we have a storage area located there (called "Northside"). Storage areas will not properly delineate the floodplain, because HEC-RAS only uses them for volume calculations (low area fills first); however, if the entire storage area was to fill, then we could map the inundation because the volume would spread over the entire storage area. This is the case at the "Southside" storage area.

Next, look at the island of water on the south side of the river denoted by an arrow. There must be as mistake here, right? How did the water get over there? We must consult the digital terrain data to determine if indeed water could get over there. After checking the Terrain TIN, we find that there is no way water could have gotten over there, so we must go back to HEC-RAS model and add levees which will keep water from flowing out in that portion of the cross section and restrict our bounding polygon. We will do this for the other areas under suspicion (as noted by the arrows) on the river's south bank, using the HEC-RAS Graphical Cross Section Editor (Figure 7-49) to add levees at the cross sections of interest.

Other options for removing extraneous areas of ponding are to reduce the width of the cross section (not recommended) or to modify the bounding polygon before performing the floodplain delineation step.

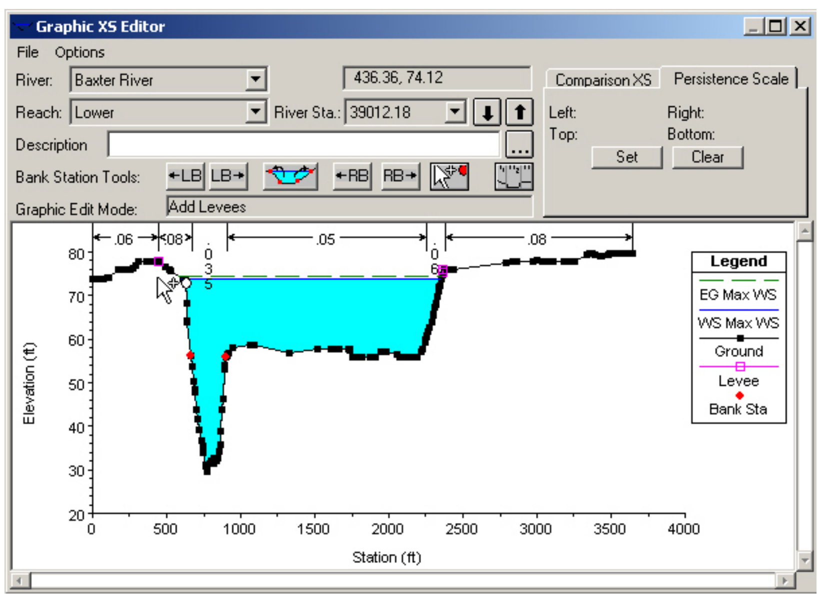


Figure 7-49. Use the HEC-RAS graphical cross section editor to add levees.

After adding additional levees on high ground in HEC-RAS, you will need to rerun HEC-RAS to compute new water surface profiles, export the results, and then perform the GeoRAS post-processing to visualize the results to the floodplain. The modified floodplain is shown in Figure 7-50. Note that we still have a few very small isolated areas of flooding. Again, this is not hydraulically correct. We could fix this through better placement of our levee or modifying our bounding polygon. As you can see, this is an iterative process that requires many iterations between HEC-RAS and the GIS to come up with results that are hydraulically correct. We will move on with our example, neglecting further refinement.

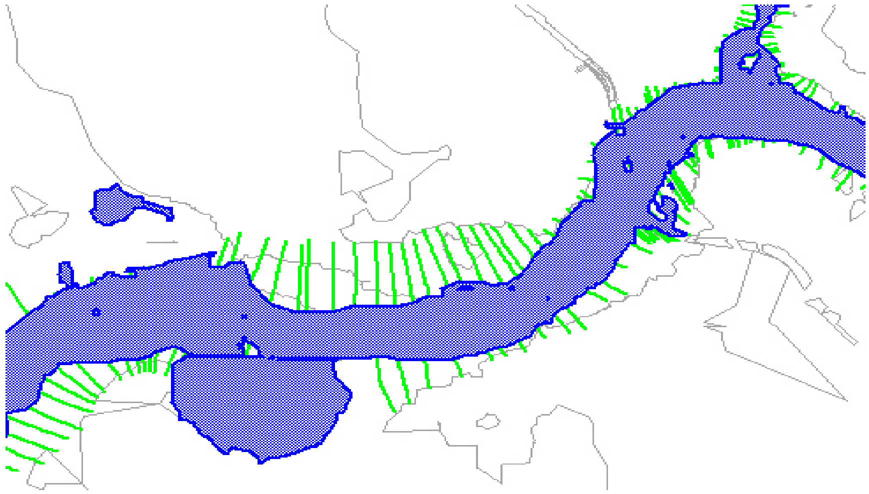


Figure 7-50. Floodplain inundation map results after adding levees to the hydraulic model.

You can now turn on the depth grid and use the various tools to pan, zoom, and identify resultant depths in the floodplain. Using the depth grid with a color gradient will allow you to quickly identify areas flooded to greater (or lesser) depth. The **Identify** tool will allow you find water depths at various locations, as illustrated in Figure 7-51.

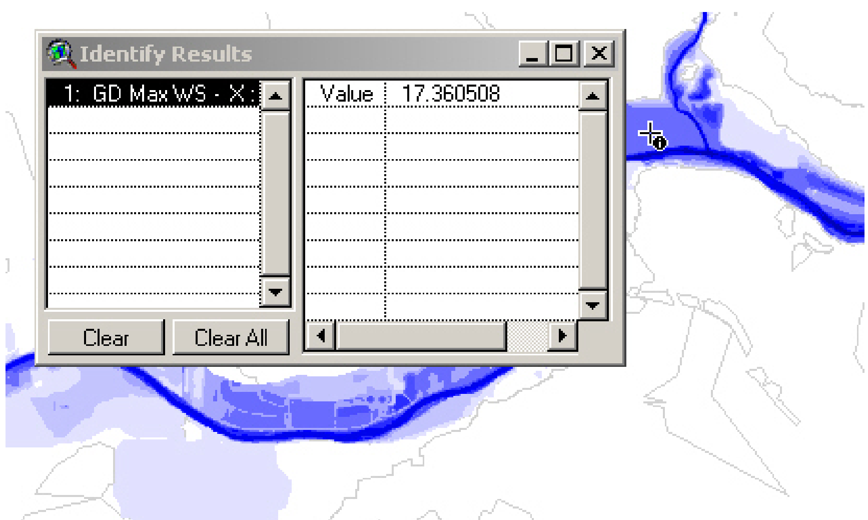


Figure 7-51. Flood depth grid with Identify Results window.

Further, you will want to zoom in along the edge of the floodplain and determine whether the grid cell size you used is small enough to accurately delineate the floodplain. In this example, we used a 20ft grid cell size, but for other studies this may not be the best choice.

Velocity TIN

Select the **postRAS ⇒ Velocity TIN Generation** menu item. This will create a velocity surface from the "VP MaxWS" point shapefile and will add it to the view. Note that the interpolation is based purely on the layout of the points and the internal triangulation criteria used by ArcView GIS. You will need to scrutinize your results and see if they make sense!

Velocity Grid

Select the **postRAS ⇒ Velocity Grid Generation** menu item. This will create a grid from the velocity TIN. Again, you can use the velocity grid to analyze the results of the hydraulics model. At each cross section the velocity results computed in HEC-RAS will be correctly represented; however, as you depart from the cross sections the velocity estimates accuracy will be reduced. An example velocity grid is shown in Figure 7-52.

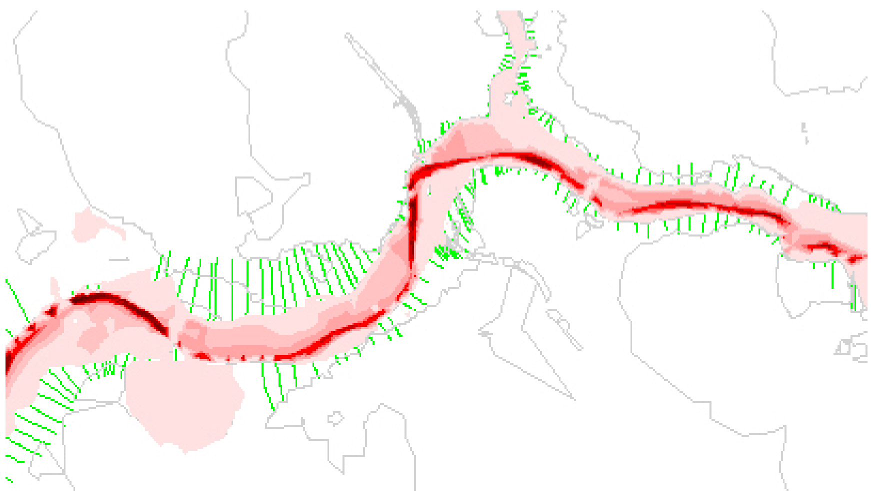


Figure 7-52. Example velocity grid.

Appendix A

References

Environmental Systems Research Institute (1996). *ArcView GIS: Using ArcView GIS*, Environmental Research Institute, Inc., Redlands, CA

Hydrologic Engineering Center (2002). *HEC-RAS (Version 3.1), River Analysis System, User's Manual*, U.S. Army Corps of Engineers, Davis, CA.

Hydrologic Engineering Center (2002). *HEC-RAS (Version 3.1), River Analysis System, Hydraulic Technical Reference Manual*, U.S. Army Corps of Engineers, Davis, CA.

Hydrologic Engineering Center (2002). *HEC-RAS (Version 3.1), River Analysis System, Applications Manual*, U.S. Army Corps of Engineers, Davis, CA.

Appendix B

HEC-RAS Import/Export Files for Geospatial Data

At version 2.0, HEC-RAS introduced three-dimensional (3D) geometry for the description of river networks and cross-sections. This capability makes it possible to import channel geometry from CADD or GIS programs without conversion from real-world coordinates to station-elevation descriptions for the cross sections, as HEC-2 required. Similarly, water-surface elevations calculated at cross sections can be exported to CADD or GIS programs, where they can be used to create model water surfaces for inundation mapping.

Supported HEC-RAS Data Exchange

Using a formatted ASCII text file, HEC-RAS Version 3.1 will import a basic description of the channel geometry including:

- The structure of the stream network, as represented by interconnected reaches.
- The location and description of cross sections.
- Manning's *n* values for each cross section.
- Levee positions (limited to one per bank) and elevations.
- Ineffective flow area positions and elevations.
- Storage area elevation-volume data.

Using the same file format, HEC-RAS can write a file exporting the results of a hydraulic model run to a CADD or GIS program. At a minimum, reported results include the locations of cross sections and the calculated water-surface elevations at those cross sections.

The Import/Export Data File Structure

This section gives general rules for the construction of an HEC-RAS geometric data import or export file. It is not necessary to understand all these rules to build an import file, but they may be useful when debugging failed imports. The rules given here are a portion of the definition of a general-purpose geometric data exchange format being developed at HEC for its NexGen model programs. **Note: These file formats are evolving, in that additional data types will be added, and some of the existing ones may be modified for future versions. If you are writing software to read and write these file formats, please keep in mind that you may need to modify your software to stay compatible with future versions of HEC-RAS.**

Records and Keywords

The HEC-RAS geometric data import file is composed of records, which in turn are composed of keywords and values. All records must contain one keyword, and all keywords end with a colon (:). A record can also contain a value or a set of values following the keyword, i.e., after the colon. Spaces, tabs, or line ends can be placed between a keyword and values within a record.

A record that contains a keyword and no value marks the beginning or the end of a group of related records (for example, the record "BEGIN HEADER:" marks the beginning of the header section of a data file). A record that contains a keyword and a value assigns that value to the part of the model named by the keyword.

When a keyword is read, all spaces up to the colon are removed and all letters are capitalized. The keywords "Begin Header:", "Begin header:", and " Be GiNH eadEr:" are all equivalent to "BEGINHEADER:". For readability, keywords named in this manual will contain internal spaces.

Values

A record can assign a single value to a single variable, or multiple values to an array. Values can be integers, floating point numbers, text strings, or locations (X,Y,Z, label). A single value in an array of values is called an "element" of that array.

A **numerical value (integer or floating point)** cannot contain internal blanks. A floating point number can contain a decimal point; an integer cannot. Elements in an array of numerical values can be separated by commas, blanks, tabs, or line ends.

A **text string** can contain internal blanks, tabs, and commas, but cannot contain internal line ends. Elements in an array of text strings must be separated by line ends.

A **location** consists of three coordinate values and a label (X, Y, Z, label). The first two coordinates are planar, the third gives elevation. The coordinate values are floating point numbers, and the label can be any type of value (although the label can be restricted to a particular data type in a particular context). In certain contexts, the elevation value or the label may not be required. If a label is used, all three coordinate values must be given; the value "NULL" is valid for the elevation coordinate only. The coordinate values and the label can be separated by commas, blanks, or tabs, but a location cannot contain internal line ends. Elements in an array of locations must be separated by line ends.

Data Groups

Records in the data file can be collected in two types of groups: objects and file sections. An object is a group of records that combine to describe an entity within the model, a cross section for example. A file section is a logical or functional grouping of data, the file header, for example, is a section that contains a description of the whole file.

Objects and file sections begin and end with records that contain keywords, but no values. A file section starts with a record containing a keyword composed of the word "BEGIN" followed by the section name and a colon, and ends with a keyword composed of the word "END" followed by the section name and a colon. For example, records containing only the keywords "BEGIN HEADER:" and "END HEADER:" are used to start and end the header section of a file. An object starts with a record containing a keyword naming the object type and ends with a record containing the keyword "END:" only. For example, a cross-section object begins and ends with records containing the keywords "CROSS-SECTION:" and "END:" only.

Comments

Hash characters (#) are used to identify comments. When a hash character is encountered in the file, all data from the hash to the next line end are ignored. A line that begins with a hash is equivalent to a blank line.

HEC-RAS Channel Geometry Import File

HEC-RAS reads channel geometry from a text file composed of three data sections:

- A header, containing descriptions that apply to all data in the file.
- A description of the stream network, containing reach locations and connectivity.
- A description of the model cross-sections, containing their location on the stream network and data required to support the HEC-RAS model.

An example HEC-RAS Channel Geometry Import file and HEC-RAS model results export file is shown at the end of this appendix.

Header

The header is bounded by the records "BEGIN HEADER:" and "END HEADER:" and must contain a record to identify the units system used in the imported data set. The units system can be US CUSTOMARY or METRIC.

```
BEGIN HEADER:


UNITS: ENGLISH

END HEADER:
```

Records that may be included in the header are listed in the Table B-1:

Table B-1

Keyword	Value Type	Value
UNITS:	string	ENGLISH or METRIC
PROFILES:	string array	List of profiles exported from HEC-RAS. Not used on import.
DTM TYPE:	string	type (e.g., TIN or raster)
DTM:	string	name of digital terrain model
STREAM LAYER:	string	name of stream layer in CADD or GIS
NUMBER OF REACHES	integer	number of hydraulic reaches contained in the file.
CROSS-SECTION LAYER:	string	name of cross-section layer in CADD or GIS
NUMBER OF CROSS-SECTIONS:	integer	number of cross sections in the file
MAP PROJECTION:	string	projection (coordinate) system used (e.g., STATEPLANE)
PROJECTION ZONE:	string	projection zone (if applicable, e.g., 5101)
DATUM:	string	reference datum for planar coordinates
VERTICAL DATUM:	string	reference datum for vertical coordinates

Stream Network

The stream network section is bounded by the records "BEGIN STREAM NETWORK:" and "END STREAM NETWORK:" and contains records describing reaches and reach endpoints. At a minimum, the stream network section must contain at least two endpoints and one reach. The minimum requirements for a stream network are shown below.

```
BEGIN STREAM NETWORK:
   ENDPOINT:  476132.66, 65291.86, 155.28, 1
   ENDPOINT:  478144.53, 64296.61, 123.72, 2

   REACH:
      STREAM ID: Below Springfield
      REACH ID: Blue River
      FROM POINT: 1
      TO POINT: 2
      CENTERLINE:
         476132.66, 65291.86, 155.28, 23.13
         476196.08, 65196.61, 154.47, 23.09
            lines omitted
         478144.53, 64296.61, 123.72, 22.41
   END:
END STREAM NETWORK:
```

A reach endpoint is represented by a record containing the keyword "ENDPOINT:" followed by four comma-delimited fields containing the endpoint's X,Y,Z coordinates and an integer ID.

A reach is represented by a multi-record object that begins with a record containing only the keyword "REACH:" and ends with a record containing only the keyword "END:." At a minimum, a reach object must contain records setting values for a stream ID, a reach ID, a FROM point, and a TO point. A reach=s FROM and TO point IDs must match IDs for endpoints listed before the reach object in the file. The reach object must also contain an array of locations defining the stream centerline. This array begins with a record containing only the keyword "CENTERLINE:" and ends when any keyword is encountered. A location element in the array contains the X, Y, and Z coordinates of a point on the stream centerline, and the point=s river station. In HEC-RAS, elevation and stationing are optional in the stream network definition. If a location element includes a station value, it must occupy the fourth field in the element. If the elevation is not known, the word "null" must take its place.

Station values are assumed to be in miles for data sets in English units, and in kilometers for data sets in metric units. Stationing is used for indexing locations along reaches, and is not used to precisely locate objects in the model.

Records that may be included in a stream network section are listed in Table B-2:

Table B-2

Keyword	**Value Type**	**Value**
ENDPOINT:	location	coordinates and integer ID
REACH:	none	marks beginning of reach object
END:	none	marks end of reach object
The following records are required for a reach object.		
STREAM ID:	string	identifies reach's membership in stream
REACH ID:	string	unique ID for reach within stream
FROM POINT:	string	integer reference to upstream endpoint
TO POINT:	string	integer reference to downstream endpoint
CENTERLINE:	location array	array elements contain coordinates and (optionally) floating point station value.

Cross Sections

The cross-sectional file section begins with a record containing the only the keyword "BEGIN CROSS-SECTIONS:" and ends with a record containing the only the keyword "END CROSS-SECTIONS:." A cross section is represented by multi-record object beginning with a record containing only the keyword "CROSS-SECTION:" and ending with a record containing only the keyword "END:."

A cross-sectional object must include records identifying the stream, reach, and station value of the cross-section, a 2D cut line, and a series of 3D locations on the cross section. Stationing is given in miles for data sets with plane units of feet and in kilometers for data sets with plane units of meters. A cut line is composed of the label "CUT LINE:" followed by an array of 2D locations. A cross-sectional polyline consists of the label "SURFACE LINE:" plus 3D coordinates written as comma-delimited X, Y, Z real-number triples, one triple to a line.

Records that may be included in the cross-section file section are listed in Table B-3:

Table B-3

Keyword	Value Type	Value
CROSS-SECTION:	none	marks beginning of cross-section object
END:	none	marks end of cross-section object
The following records are required for a cross-section object.		
STREAM ID:	string	identifiers for stream and reach where cross-section is located (must refer to existing streams and reaches in the model)
REACH ID:	string	
STATION:	floating point	relative position of cross-section on stream
CUT LINE:	location array	array elements contain 2D coordinates of cross sectione stike line
SURFACE LINE:	location array	array elements contain 3D coordinates of cross section points
The following records are optional for a cross-section object.		
BANK POSITIONS:	floating point (2 elements)	Fraction of length along cut line where main channel bank stations are located. (values 0.0 - 1.0)
REACH LENGTHS:	floating point (3 elements)	Distance along left overbank, center channel, and right overbank flow paths to next cross-section downstream (units are feet or meters).
NVALUES:	floating point (n paired elements)	Manning's n values expressed as fraction along cut line to start of n-value *(fraction, n-valu*e).
LEVEE POSITIONS:	String, + 2 floating point elements	Levee positions expressed as fraction along cut line to position with elevation *(ID, fraction, elevation)*.
INEFFECTIVE POSTIONS:	String, + 3 floating point elements	Ineffective flow areas expressed as a fraction along cut line to beginning and end positions with trigger elevation *(ID, begin fraction, end fraction, elevation)*.
WATER ELEVATION:	floating point array	Water surface elevation values. Used for export of model results. Not read on import.

Additional Properties

In addition to the cross-sectional properties, levee alignment, ineffective flow area, and storage area data may be written to the geometric data exchange file. This data is written to the file after the "END-CROSS-SECTIONS:" header. With the exception of the storage area elevation-volume data, the additional properties data is used for display purposes in HEC-RAS. Additional geometric data, not required for HEC-RAS, are listed in Table B-4.

Table B-4

Keyword	**Value Type**	**Value**
Levee records		
BEGIN LEVEES:	none	Marks beginning of levee object
LEVEE ID:	string	Levee identifier. Corresponds to *ID* in LEVEE POSITIONS object at cross section
SURFACE LINE:	location array	Array elements contain 3D coordinates of levee profile points. Array concludes with END:.
END LEVEES:	string	Marks end of levee object
Ineffective flow area records		
BEGIN INEFFECTIVE AREAS:	none	Marks beginning of ineffective flow object.
INEFFECTIVE ID:	string	Ineffective flow area identifier. Corresponds to *ID* in INEFFECTIVE POSITIONS object at cross section
POLYGON:	location array	Array elements contain 3D coordinates of ineffective flow polygon points*(X, Y, Elevation)*. Array concludes with END:.
END INEFFECTIVE AREAS:	none	Marks end of ineffective flow object.
Storage area records		
BEGIN STORAGE AREAS:	none	Marks beginning of storage area object.
SA ID:	string	Storage area identifier.
SURFACE LINE:	location array	Array elements contain 3D coordinates of storage area polygon points. Array concludes with END:.
ELEVATION-VOLUME:	floating point array	Describes elevation-volume relationship for *SA ID* with paired data *(elevation, volume)*. Array concludes with END:.
TERRAIN:	floating point array	Describes terrain in vicinity of storage area in 3D point data *(X, Y, Elevation).* Array concludes with END:.
END STORAGE AREAS:	none	Marks end of storage area object

HEC-RAS Model Results Export File

HEC-RAS exports model results to a text file using the same format as the data import file. The contents of the files, however, are not identical. The stream network section is not required for data export, and the surface line may be omitted from the cross-section objects. An example HEC-RAS model export file is shown at the end of this discussion. Model results are reported with the following elements (Table B-5), which are not required (and are not read) in the import file.

Table B-5

Keyword	**Value Type**	**Value**
The following record is optional in the Header section of the export file.		
PROFILE NAMES:	string array	Name(s) of water surface profiles reported in the file. This record is required if more than one profile is reported.
The following record is required for each cross-section object.		
WATER ELEVATIONS:	floating point array	Elevation of water surface at the cross-section. The array must contain one value for each profile.
The following records are optional for a cross-section object.		
PROFILE ID:	string	Water surface profile name. This must match a name in the Profile Names record in the header.
VELOCITIES:	floating point (pair)	Fraction along cut line and value of velocity (*fraction, value*). *Velocities record must follow Profile ID record.*
WATER SURFACE EXTENTS:	location array	A series of 2D locations marking the limits of a water surface.
The following records make up a section defining a bounding polygon of the water surface limits.		
BEGIN BOUNDARIES:	none	Marks start of boundaries file section.
END BOUNDARIES:	none	Marks end of boundaries file section.
PROFILE LIMITS:	none	Marks start of an object defining the limits of a single water surface profile.
PROFILE ID:	string	Name of profile. This must match a name in the Profile Names record in the header.
POLYGON:	location array	A series of 2D locations marking the limits of a water surface. A single profile limit can be merged from multiple polygons.

- HEC-RAS allows the user 16 character profile names. Profile names must begin with a letter.
- If no profile name is provided, only one water elevation will be written for each cross section.

Water Surface Bounding Polygon

In addition to a water surface elevation at each cross section (one for each profile), the HEC-RAS program sends a bounding polygon for each hydraulic reach in the model (the program outputs a new set of bounding polygons for each profile computed). The bounding polygon is used as an additional tool in assisting the GIS (or CADD) software to figure out the boundary of the water surface on top of the terrain.

In most cases, the bounding polygon will represent the outer limits of the cross section data, and the actual intersection of the water surface with the terrain will be inside of the polygon. In this case, the GIS software will use the water surface elevations at each cross section and create a surface that extends out to the edges of the bounding polygon. That surface is then intersected with the terrain data, and the actual water limits are found as the location where the water depth is zero.

However, is some cases, the bounding polygon may not represent the extents of the cross-section data. For example, if there are levees represented in the HEC-RAS model, which limit the flow of water, then the bounding polygon will only extend out to the levees at each cross section. By doing this, when the information is sent to the GIS, the bounding polygon will prevent the GIS system from allowing water to show up on both sides of the levees.

In addition to levees, the bounding polygon is also used at hydraulic structures such as bridges, culverts, weirs, and spillways. For example, if all of the flow is going under a bridge, the bounding polygon is brought into the edges of the bridge opening along the road embankment on the upstream side, and then back out to the extent of the cross-section data on the downstream side. By doing this, the GIS will be able to show the contraction and expansion of the flow through the hydraulic structures, even if the hydraulic structures are not geometrically represented in the GIS.

Another application of the bounding polygon is in FEMA floodway studies. When a floodway study is done, the first profile represents the existing conditions of the flood plain. The second and subsequent profiles are run by encroaching on the floodplain until some target increase in water surface elevation is met. When the encroached profile is sent to the GIS, the bounding polygon is set to the limits of the encroachment for each cross section. This will allow the GIS to display the encroached water surface (floodway) over the terrain, even though the water surface does not intersect the ground.

Import/Export Guidelines

The following rules apply to channel and cross-section import/export data.

Defining The Stream Network

- The stream network is represented by a set of interconnected reaches. A stream is a set of one or more connected reaches that share a common stream ID.
- A stream is composed of one or more reaches with the same stream ID, and each reach in a stream must have a unique reach ID. Every reach must be identified by a unique combination of stream and reach IDs.
- Stream IDs and Reach IDs are alphanumeric strings up to 16 characters long. Reach endpoint IDs are integers.
- Streams cannot contain parallel flow paths. (If three reaches connect at a node, only two can have the same stream ID.) This prevents ambiguity in stationing along a stream.
- A reach is represented by an ordered series of 3D coordinates, and identified by a stream ID, a reach ID, and IDs for its endpoints.
- A reach endpoint is represented by its 3D coordinates and identified by an integer ID.
- Reaches are not allowed to cross, but can be connected at their endpoints (junctions) to form a network.
- The normal direction of flow on a reach is indicated by the order of its endpoints. One point marks the upstream or "from" end of the reach, the other marks the downstream or "to" end of the reach.

Defining Cross Sections

- Each cross section is defined by a series of 3D coordinates, and identified by a stream name and reach name (which must refer to an existing stream and reach) and a station, indicating the distance from the cross-section to the downstream end of the stream.
- A cross-section line can cross a reach line exactly once, and cannot cross another cross-section line.

Results of a water surface calculation are exported in a file that contains cross-section locations in plane (2D) coordinates, water-surface elevations for the cross-sections, and boundary polygons for the reaches.

Water Surface Export Data Rules

- A cross-section is represented by a water surface elevation and a series of 2D coordinates on the cross-section cut line. The full width of the cross-section is included.
- One bounding polygon is created for each reach in the stream network, and for each profile.
- A reach's bounding polygon is made up of the most upstream cross-section on the reach, the endpoints of all cross-sections on the reach, and the most upstream cross-sections of reaches downstream of the reach.
- For purposes of defining bounding polygons *only*, the endpoints of a cross-section are adjusted to the edge of the water surface at the cross-section if the cross-section is part of a floodway, a leveed section of the reach, or the water extent is controlled by a hydraulic structure. This allows calculated water surfaces that are higher than the land surface to be reported back to the CADD or GIS program.

Sample HEC-RAS Geometry Import File

```
BEGIN HEADER:

  DTM TYPE: TIN
  DTM: d:\georas\wailupe\wai_tin
  STREAM LAYER: d:\georas\wailupe\stream3d.shp
  NUMBER OF REACHES: 3
  CROSS-SECTION LAYER: d:\georas\wailupe\xscutlines3d.shp
  NUMBER OF CROSS-SECTIONS: 40
  MAP PROJECTION: STATEPLANE
  PROJECTION ZONE: 5103
  DATUM: NAD27
  UNITS: ENGLISH

END HEADER:


BEGIN STREAM NETWORK:

  ENDPOINT: 582090.487, 49258.898, 218.609, 1
  ENDPOINT: 582331.707, 47063.536, 114.164, 2
  ENDPOINT: 583735.405, 47715.344, 278.222, 3
  ENDPOINT: 584138.295, 41249.225, 1.140, 4

  REACH:
    STREAM ID: Wailupe
    REACH ID: Upper
    FROM POINT: 1
    TO POINT: 2
    CENTERLINE:
      582090.487, 49258.898, 218.609, 8640.151
many lines omitted
      582331.707, 47063.536, 114.164, 6402.057
  END:

  REACH:
    STREAM ID: Kului Gorge
    REACH ID: Tributary
    FROM POINT: 3
    TO POINT: 2
    CENTERLINE:
      583735.405, 47715.344, 278.222, 1813.116
many lines omitted
      582331.707, 47063.536, 114.164, -0.000
  END:

  REACH:
```

```
        STREAM ID: Wailupe
        REACH ID: Lower
        FROM POINT: 2
        TO POINT: 4
        CENTERLINE:
          582331.707, 47063.536, 114.164, 6402.057
    many lines omitted
          584138.295, 41249.225, 1.140, 0.000
      END:

    END STREAM NETWORK:

    BEGIN CROSS-SECTIONS:

      CROSS-SECTION:
        STREAM ID: Wailupe
        REACH ID: Lower
        STATION: 220.827
        BANK POSITIONS: 0.50343, 0.51543
        REACH LENGTHS: 87.418, 220.827, 159.365
        NVALUES:
          0.00000,0.150
          0.50213,0.035
          0.53983,0.150
        LEVEE POSITIONS:
          leftlevee, 0.11314, 240.05
          rightlevee, 0.68370, 240.12
        INEFFECTIVE POSITIONS:
          IneffArea1, 0.00000, 0.16538, 9.07
        CUT LINE:
          586214.122, 42127.918
          581980.991, 40806.059
        SURFACE LINE:
          586214.122, 42127.918, 4.007
    many lines omitted
          581980.991, 40806.059, 6.390
      END:
```

many Cross sections omitted

```
      CROSS-SECTION:
        STREAM ID: Wailupe
        REACH ID: Lower
        STATION: 6269.258
        BANK POSITIONS: 0.52237, 0.56932
        REACH LENGTHS: 170.100, 164.521, 158.965
        NVALUES:
          0.00000,0.066
          0.19234,0.150
          0.47239,0.035
          0.56874,0.150
```

```
          0.94231,0.066
        INEFFECTIVE POSITIONS:
          IneffArea1, 0.16534, 0.21538, 3.04
          IneffArea2, 0.34321, 0.44223, 2.69
        CUT LINE:
          582723.174, 46846.449
          582426.438, 46878.916
          581953.514, 47082.992
        SURFACE LINE:
          582723.174, 46846.449, 161.917
    many lines omitted
          581953.514, 47082.992, 165.010
      END:

      CROSS-SECTION:
        STREAM ID: Wailupe
        REACH ID: Upper
        STATION: 6822.378
        BANK POSITIONS: 0.49244, 0.55533
        REACH LENGTHS: 142.689, 139.905, 126.201
        NVALUES:
          0.00000,0.066
          0.27498,0.150
        CUT LINE:
          582774.257, 47502.740
          582593.433, 47493.464
          582343.062, 47465.635
          582083.418, 47502.740
        SURFACE LINE:
          582774.257, 47502.740, 170.548
    many lines omitted
          582083.418, 47502.740, 164.059
      END:
```

many *Cross sections omitted*

```
      CROSS-SECTION:
        STREAM ID: Wailupe
        REACH ID: Upper
        STATION: 8032.371
        BANK POSITIONS: 0.42694, 0.47784
        REACH LENGTHS: 206.927, 210.604, 211.292
        NVALUES:
          0.00000,0.066
          0.15324,0.150
          0.68394,0.066
        CUT LINE:
          582496.067, 48736.476
          582190.057, 48657.628
          581893.321, 48625.161
        SURFACE LINE:
```

```
      582496.067, 48736.476, 241.056
        many lines omitted
      581893.321, 48625.161, 231.414
  END:

  CROSS-SECTION:
    STREAM ID: Kului Gorge
    REACH ID: Tributary
    STATION: 1089.584
    BANK POSITIONS: 0.37339, 0.57995
    REACH LENGTHS: 263.179, 255.877, 223.864
    NVALUES:
      0.00000,0.150
      0.48348,0.055
      0.59834,0.150
      0.70202,0.066
    CUT LINE:
      583337.968, 47187.952
      583207.930, 47327.062
      583153.496, 47381.496
      583126.279, 47608.306
    SURFACE LINE:
      583337.968, 47187.952, 257.736
       many lines omitted
      583126.279, 47608.306, 326.921
  END:

  CROSS-SECTION:
    STREAM ID: Kului Gorge
    REACH ID: Tributary
    STATION: 833.707
    BANK POSITIONS: 0.37549, 0.54129
    REACH LENGTHS: 197.573, 189.074, 185.550
    NVALUES:
      0.00000,0.066
      0.16943,0.150
      0.44398,0.055
      0.60938,0.150
      0.95939,0.066
    CUT LINE:
      583223.051, 46967.190
      583071.844, 47103.276
      583020.434, 47402.665
    SURFACE LINE:
      583223.051, 46967.190, 232.596
        many lines omitted
      583020.434, 47402.665, 286.581
  END:
```

many *Cross sections omitted*

```
    CROSS-SECTION:
      STREAM ID: Kului Gorge
      REACH ID: Tributary
      STATION: 273.138
      BANK POSITIONS: 0.54139, 0.65533
      REACH LENGTHS: 139.815, 273.138, 79.293
      NVALUES:
        0.00000,0.150
        0.37784,0.055
        0.62948,0.035
        0.64874,0.150
      CUT LINE:
        582546.842, 47088.605
        582555.984, 47189.171
        582550.499, 47240.368
        582552.327, 47295.223
      SURFACE LINE:
        582546.842, 47088.605, 145.787
         many lines omitted
        582552.327, 47295.223, 144.778
    END:

  END CROSS-SECTIONS:

  BEGIN LEVEES:

    LEVEE ID: leftlevee
    SURFACE LINE:
      582686.905, 48638.117, 242.798
      582686.782, 48630.794, 242.448
        many lines omitted
      584905.959, 41579.637, 239.222
  END:
    LEVEE ID: rightlevee
    SURFACE LINE:
      582025.910, 48779.758, 242.024
      582025.910, 48777.907, 242.024
          many lines omitted
      583583.969, 41036.677, 239.356
    END:

  END LEVEES:

  BEGIN INEFFECTIVE AREAS:

    INEFFECTIVE ID: IneffArea1
    POLYGON:
      584481.034, 42523.915
      584575.461, 42759.984
       many lines omitted
      584481.034, 42523.915
```

```
  INEFFECTIVE ID: IneffArea2
  POLYGON:
    582993.795, 44365.257
    583418.720, 44719.362
      many lines omitted
    582993.795, 44365.257
  END:

END INEFFECTIVE AREAS:

BEGIN STORAGE AREAS:

  SA ID: SA_Area1
  SURFACE LINE:
    582769.822, 44692.545
    582769.822, 44701.057
      many lines omitted
    582769.822, 44692.545
  END:
  ELEVATION-VOLUME:
    40.000, 0.000
    46.000, 66435.249
    52.100, 450771.888
    58.200, 1446462.804
    64.200, 2809967.042
    70.300, 4369947.061
    76.300, 6029131.699
    82.400, 7762270.948
    88.400, 9573820.153
    94.500, 11436156.068
    100.500, 13329687.798
    106.600, 15238976.327
  END:
  TERRAIN:
    582827.853, 44749.516, 52.003
    582830.979, 44755.204, 52.003
      many lines omitted
    583268.917, 45257.861, 100.012
  END:

END STORAGE AREAS:
```

Sample HEC-RAS Geographic Data Export File

```
BEGIN HEADER:
  UNITS: ENGLISH
  DTM TYPE: TIN
  DTM: d:\georas\wailupe\wai_tin
  STREAM LAYER: d:\georas\wailupe\stream3d.shp
  CROSS-SECTION LAYER: d:\georas\wailupe\xscutlines3d.shp
  MAP PROJECTION: STATEPLANE
  PROJECTION ZONE: 5103
  DATUM: NAD27
  VERTICAL DATUM:
  NUMBER OF PROFILES:  3
  PROFILE NAMES:
    Big
    Bigger
    Biggest
  NUMBER OF REACHES:  3
  NUMBER OF CROSS-SECTIONS:  103
END HEADER:

BEGINSTREAMNETWORK:

ENDPOINT:582331.71,47063.54, , 1
ENDPOINT:582090.49,49258.90, , 2
ENDPOINT:584138.30,41249.23, , 3
ENDPOINT:583735.41,47715.34, , 4

REACH:
 STREAM ID: Wailupe
 REACH ID: Upper
 FROM POINT:  2
 TO POINT:  1
 CENTERLINE:
     582090.49,     49258.90, ,
 many line omitted
     582331.71,     47063.54, ,
 END:

REACH:
 STREAM ID: Wailupe
 REACH ID: Lower
 FROM POINT:  1
 TO POINT:  3
```

```
 CENTERLINE:
     582331.71,     47063.54, ,
many lines omitted
     584138.30,     41249.23, ,
 END:

REACH:
 STREAM ID: Kului Gorge
 REACH ID: Tributary
 FROM POINT:  4
 TO POINT:  1
 CENTERLINE:
     583735.41,     47715.34, ,
many lines omitted
     582331.71,     47063.54, ,
 END:

ENDSTREAMNETWORK:

BEGIN CROSS-SECTIONS:

  CROSS-SECTION:
    STREAM ID:Wailupe
    REACH ID:Upper
    STATION:8032.371
    CUT LINE:
      582496.067 , 48736.476
      582190.057 , 48657.628
      581893.321 , 48625.161
    BANK POSITIONS:0.42600,0.47700
    WATER ELEVATION:199.3957,200.6774,203.5746
    WATER SURFACE EXTENTS:
      582242.56,   48671.16,   582212.81,   48663.49
      582246.10,   48672.07,   582209.73,   48662.70
      582262.79,   48676.37,   582197.27,   48659.49
    PROFILE ID:Big
        VELOCITIES:
          0.43251,   5.29
          0.44147,   11.31
          0.45140,   11.48
          0.46148,   10.50
          0.46968,   4.35
    PROFILE ID:Bigger
        VELOCITIES:
          0.42484,   1.25
          0.43231,   5.93
          0.44145,   12.24
          0.45141,   12.40
          0.46151,   11.44
```

```
          0.47008,   4.88
          0.47839,   1.21
    PROFILE ID:Biggest
        VELOCITIES:
          0.41496,   3.61
          0.43201,   6.82
          0.44142,   13.32
          0.45143,   13.44
          0.46155,   12.59
          0.47070,   6.09
          0.48537,   3.64
  END:
```

Many cross sections (and interpolated cross sections) omitted

```
  CROSS-SECTION:
    STREAM ID:Wailupe
    REACH ID:Upper
    STATION:6682.474
    CUT LINE:
      582641.922 , 47366.533
      582444.447 , 47335.449
      582336.567 , 47337.277
      582062.296 , 47381.161
    BANK POSITIONS:0.38000,0.47199
    WATER ELEVATION:133.7104,135.6018,139.3349
    WATER SURFACE EXTENTS:
      582417.69,   47335.90,   582377.28,   47336.59
      582419.39,   47335.87,   582375.14,   47336.62
      582437.89,   47335.56,   582370.92,   47336.69
    PROFILE ID:Big
        VELOCITIES:
          0.39480,   4.79
          0.40794,   10.33
          0.42583,   11.09
          0.44240,   7.20
          0.45444,   1.62
    PROFILE ID:Bigger
        VELOCITIES:
          0.39368,   4.71
          0.40788,   10.07
          0.42586,   10.67
          0.44287,   7.40
          0.45565,   2.49
    PROFILE ID:Biggest
        VELOCITIES:
          0.36681,   2.52
          0.39108,   5.05
          0.40781,   10.10
```

```
        0.42589,   10.52
        0.44336,   7.84
        0.45805,   3.38
END:

CROSS-SECTION:
  STREAM ID:Kului Gorge
  REACH ID:Tributary
  STATION:1089.584
  CUT LINE:
    583337.968 , 47187.952
    583207.93 , 47327.062
    583153.496 , 47381.496
    583126.279 , 47608.306
  BANK POSITIONS:0.37300,0.57900
  WATER ELEVATION:219.1924,220.2025,221.5454
  WATER SURFACE EXTENTS:
    583192.52,   47342.48,   583177.65,   47357.34
    583193.66,   47341.33,   583176.64,   47358.36
    583195.18,   47339.81,   583175.29,   47359.70
  PROFILE ID:Big
      VELOCITIES:
        0.44533,   10.34
        0.46033,   8.44
  PROFILE ID:Bigger
      VELOCITIES:
        0.44432,   11.33
        0.46129,   9.32
  PROFILE ID:Biggest
      VELOCITIES:
        0.44296,   12.44
        0.46257,   10.34
END:
```

Many cross sections (and interpolated cross sections) omitted

```
CROSS-SECTION:
  STREAM ID:Kului Gorge
  REACH ID:Tributary
  STATION:273.138
  CUT LINE:
    582546.842 , 47088.605
    582555.984 , 47189.171
    582550.499 , 47240.368
    582552.327 , 47295.223
  BANK POSITIONS:0.54099,0.65500
  WATER ELEVATION:135.2666,136.3284,137.8818
  WATER SURFACE EXTENTS:
    582554.32,   47204.74,   582552.81,   47218.77
```

```
      582554.37,   47204.24,   582552.76,   47219.30
      582554.45,   47203.51,   582552.67,   47220.11
    PROFILE ID:Big
        VELOCITIES:
          0.56337,   1.54
          0.57644,   10.95
          0.59787,   15.34
          0.61730,   13.10
    PROFILE ID:Bigger
        VELOCITIES:
          0.56256,   2.97
          0.57620,   12.59
          0.59789,   17.18
          0.61875,   14.67
          0.63251,   1.86
    PROFILE ID:Biggest
        VELOCITIES:
          0.56137,   4.30
          0.57597,   14.31
          0.59791,   19.12
          0.61927,   16.89
          0.63330,   5.09
  END:

  CROSS-SECTION:
    STREAM ID:Wailupe
    REACH ID:Lower
    STATION:6269.258
    CUT LINE:
      582723.174 , 46846.449
      582426.438 , 46878.916
      581953.514 , 47082.992
    BANK POSITIONS:0.52401,0.56900
    WATER ELEVATION:123.9078,125.2825,127.845
    WATER SURFACE EXTENTS:
      582309.53,   46929.36,   582276.02,   46943.82
      582309.55,   46929.35,   582275.92,   46943.87
      582326.40,   46922.09,   582195.49,   46978.57
    PROFILE ID:Big
        VELOCITIES:
          0.52365,   2.47
many lines omitted
          0.56408,   1.21
    PROFILE ID:Bigger
        VELOCITIES:
          0.52363,   2.70
many lines omitted
          0.56380,   1.27
    PROFILE ID:Biggest
```

```
          VELOCITIES:
            0.51786,   2.90
many lines omitted
            0.66018,   0.35
  END:
```

Many cross sections (and interpolated cross sections) omitted

```
  CROSS-SECTION:
    STREAM ID:Wailupe
    REACH ID:Lower
    STATION:220.827
    CUT LINE:
      586214.122 , 42127.918
      581980.991 , 40806.059
    BANK POSITIONS:0.50300,0.51500
    WATER ELEVATION:5.503006,5.881266,6.600093
    WATER SURFACE EXTENTS:
      586214.12,   42127.92,   583114.30,   41159.95
      586214.12,   42127.92,   581980.99,   40806.06
    PROFILE ID:Big
        VELOCITIES:
          0.00851,   0.55
many lines omitted
          0.71676,   0.18
    PROFILE ID:Bigger
        VELOCITIES:
          0.00855,   0.63
many lines omitted
          0.72186,   0.25
    PROFILE ID:Biggest
        VELOCITIES:
          0.01783,   0.55
many lines omitted
          0.99398,   0.11
  END:

END CROSS-SECTIONS:

BEGIN STORAGE AREAS:
  SA ID: SA_Area1
     WATER ELEVATION: 5.2454, 5.65658, 6.12648
  SURFACE LINE:
    582769.822, 44692.545
    582769.822, 44701.057
      many lines omitted
    582769.822, 44692.545

  END:
```

```
END STORAGE AREAS:

BEGIN BOUNDS:
  PROFILE LIMITS:
    PROFILE ID:Big
    POLYGON:
      581893.32 , 48625.16
many lines omitted
      581908.77 , 48563.31
    POLYGON:
      583126.27 , 47608.3
many lines omitted
      583090.99 , 47539.75
    POLYGON:
      581953.51 , 47082.99
many lines omitted
      581934.96 , 47008.78
  END:

  PROFILE LIMITS:
    PROFILE ID:Bigger
    581893.32 , 48625.16
many lines omitted
      581908.77 , 48563.31
    POLYGON:
      583126.27 , 47608.3
many lines omitted
      583090.99 , 47539.75
    POLYGON:
      581953.51 , 47082.99
many lines omitted
      581934.96 , 47008.78
  END:

  PROFILE LIMITS:
    PROFILE ID:Biggest
    581893.32 , 48625.16
many lines omitted
      581908.77 , 48563.31
    POLYGON:
      583126.27 , 47608.3
many lines omitted
      583090.99 , 47539.75
    POLYGON:
      581953.51 , 47082.99
many lines omitted
      581934.96 , 47008.78
  END:
END BOUNDS:
```